PERIODICAL
UNIVERSITY OF HAWAII
LIBRARY

OUTLOOK ON AGRICULTURE

Volume II Number 4

Summer 1959

The design in linocut on the cover is a composite of drawings from two medieval manuscripts. In the centre is a figure from the works of Matthew Paris, who entered St. Alban's as a monk in 1217. Surrounding this, depicting farming activities throughout the year, are drawings based on MS. from the Benedictine Abbey of Sweifalten, circa 1162.

OUTLOOK ON AGRICULTURE

VOLUME II · SUMMER 1959 · NUMBER 4

PAGE

150 *Editorial: The Chemical Control of Bracken*

151 *The Manuring of Tea* T. EDEN, D.Sc., F.R.I.C.

158 *The Bracken Problem* E. CONWAY, B.Sc., Ph.D.

168 *Seed Treatment of Cotton against Diseases and Insect Pests* S. A. J. TARR, B.Sc., Ph.D.

178 *The Use of Viruses in the Biological Control of Insect Pests* KENNETH M. SMITH, C.B.E., D.Sc., Ph.D., F.R.S.

185 *Clostridial Diseases of Sheep* JOHN T. STAMP, D.Sc., M.R.C.V.S., F.R.S.E.

192 *Book Reviews*

194 *Abstracts*

Communications should be addressed to the Editor, E. J. McNaughton, B.Sc. (Hons.), B.Sc. (Agric.),
Imperial Chemical Industries Limited, Jealott's Hill Research Station, Bracknell, Berkshire, England

THE CHEMICAL CONTROL OF BRACKEN

It is not uncommon to hear the view expressed that bracken-infested land is of intrinsically low value, fit only to harbour a scattered flock of hardy hill sheep, and not worth the expenditure of cash or effort on attempts to control the weed. This is a specious and a defeatist argument. Bracken is of course prevalent in hill areas so hostile and barren that the cost of almost any kind of land improvement cannot be contemplated; but the plant prefers a fertile soil and its vigorous growth is directly responsible for rapid deterioration of the sward on potentially good grazing land. Thus the timely control of bracken as it begins to invade such land is likely to be of value to the farmer, and here at least the problem of devising effective control techniques is not to be lightly brushed aside on grounds of economy.

This realistic view of the situation has long been taken by a small group of research workers in Scotland. They rightly look on the presence of bracken as a cause rather than a consequence of poor land, and for over a quarter of a century they have consistently striven to control the weed although for most of that time the hope of achieving really good results must have seemed small—cut bracken and it merely comes again; apply total weedkillers and it still survives. Those concerned with the development of chemical techniques for killing weeds know only too well how essential it is to have a sound knowledge of the "enemy" in order to plan an attack, and the Scottish workers prepared for the future by determining the precise manner in which bracken grows and spreads.

Their chance came with the introduction of the synthetic growth-regulator herbicides during and after the war. By this time the essentials for a chemical treatment that would kill bracken had become known, and at Glasgow University Dr. Conway developed a screening test to evaluate "candidate" bracken-killers with these criteria in mind. From the many compounds examined one translocatable material was recently selected for its ability to suppress bracken growth not only during the season of treatment but in subsequent years. This new chemical—discovered in the U.S.A.—has passed its preliminary trials satisfactorily and is now on the threshold of commercial production. Much research remains to be done before the full capabilities of the chemical are known and it may be that in the course of time better materials will replace it.

Methods must also be found for its practical application. On many areas where bracken is encroaching on cultivated or "in-bye" land the problem is fairly straightforward: an ordinary low-volume spraying machine with a hand lance will cope effectively with the weed. On hill grazings difficult of access, however, recourse may be necessary to caterpillar tractors fitted with sprayers, or even to low-volume knapsack sprayers if the areas to be treated are small enough. Where vast tracts of hill are involved thoughts turn to the use of aircraft. In New Zealand recent experiments with weedkillers against gorse have made it clear that on hill areas away from cultivated land aircraft are the most useful and efficient means of applying the chemicals. The precedent was therefore established and already work is in hand to test helicopters for applying weedkillers to bracken in the U.K. Should this method be successful and reasonable in cost it may make bracken control feasible even in remote areas.

What is the farmer's reaction to the prospect of controlling bracken? In the days before the war when he had more permanent pasture than his stock could graze and farming did not pay, he was inclined to abandon the poorer areas to the weed. But times have changed. About one-third of the old pasture land has come under the plough, and more stock must now be carried on fewer grazing acres. Farmers everywhere have already adopted modern herbicides, and from consultation with those who have bracken-infested land it is evident that many of them will welcome the opportunity of testing the chemical, at any rate on areas easy of access.

Even if the new chemical does not come up to expectations scientist and farmer can henceforward look on the bracken problem as one that sooner or later will be solved. Indeed, control of the weed may perhaps be achieved with surprising efficiency and economy. It is not only that the underground stem which made the plant wellnigh invulnerable to destruction by the older herbicides has now become its Achilles' heel: bracken is a fern, not a seed plant, and if it is true that it rarely reproduces itself by spores in Britain it is conceivable that a few foliage sprayings may clear an infested area for all time. This of course is mere hypothesis, and for several years to come the aim must be to secure good control rather than eradication.

THE MANURING OF TEA

T. Eden

(*formerly Director of the Tea Research Institute of East Africa, Kericho, Kenya*)

Most of the soils on which tea is grown are of low fertility, and high yields cannot be obtained without liberal manuring. Nitrogen is the chief requirement, and its application up to 100 lb. per acre will usually give economic responses from tea in good condition if local needs of phosphate and potash are met. Account must also be taken in treating the crop of such important factors as type of tea, age of the bushes, and the pruning regime.

The development of manurial practice in the tea industry is marked by four well-defined phases. The first is one of thoroughgoing exploitation of soil resources with no thought for the drain on fertility that the constant removal of crop entails. At this time little was known about soil science, and the luxuriant vegetation in warm climates with abundant rainfall encouraged the belief that soil fertility was high.

Tea growing in India started in the 1830s, but with the exception of cattle manure there is no mention in the literature of the use of manurial supplements until the turn of the century. In 1907 oil cakes of local origin were in use, but artificial manures had yet to make their appearance [21]. In Ceylon tea was first planted in the 1870s to replace coffee, which was rapidly being wiped out by the devastating coffee-rust disease (*Hemileia vastatrix*), and here too many years had to elapse before serious attempts were made to safeguard soil nutrient resources or to stimulate higher crop production by manuring.

The second period, from the beginning of the present century until the end of the first world war, saw the development of organized manuring and the importation of artificial fertilizers. Nitrogenous fertilizers were chiefly in the form of oil cakes and fish offal. Progress during this phase is well illustrated by the Ceylon Customs returns, which show that between 1900 and 1916 the imports of nitrogenous manures, expressed in terms of nitrogen, increased from 500 to 12,000 tons per annum. War conditions caused a recession, which continued until 1922.

During the third period, extending until the disturbing effects of the second world war had moderated, several factors influenced fertilizer trends. There was a notable increase in research activities. North India and Java had tea research institutes actively at work, and Ceylon and South India established theirs in the 1920s. Field experiments furnished accurate information about fertilizer responses, and by 1939 Ceylon was importing more than 20,000 tons of nitrogen per annum, most of it used on tea plantations. Further expansion was checked by the Tea Regulation Scheme which started in 1933, because it was unprofitable to manure crops that could not be marketed.

The decline in manuring that occurred during the war, and for four or five years subsequently, was much more severe than in the previous war period. The ratio of organic to inorganic nitrogen then in use was seven: before the second war period it was less than one [10]. Sulphate of ammonia became scarce, and for a time its importation was discontinued. Rationing was introduced, and the allocated supplies of all fertilizers were distinctly below those needed to keep tea in good condition. Because of these restrictions in crop and fertilizers the knowledge of how to increase yields could not be brought to fruition.

The fourth phase, which followed when fertilizers became freely available about a decade ago, has been marked by a steep rise in yields per acre, due mainly to liberal manuring.

SOILS AND CLIMATE

Tea is grown on a wide variety of soils. Those of the tea districts of Ceylon and South India are derived from Archaean rocks. Large areas of Assam are covered with river alluvium of the Quaternary period. East Africa and the Indonesian localities are largely of volcanic origin. The types of soil have been conditioned less by the geological formation than by the intensive weathering processes to which they have been subjected.

Tea-growing is not commercially practicable in climates with a rainfall lower than 40–50 in. per annum. In practice tea is cultivated in regions of rainfall rising from this lower limit to more than 200 in. per annum. Thus, all productive tea soils have been highly leached through the agencies of weathering and erosion, and compared with agricultural soils of the temperate zone they are of low

TABLE I

NUTRIENT STATUS OF TYPICAL TEA SOILS

(Percentages: High shown over Low)

Location	N	P		K	
		Total	Available	Total	Available
Assam Valley ..	0·10 0·08	0·09 0·04	0·015 0·006	— —	0·019 0·005
Surmah Valley ..	0·57 0·15	0·34 0·07	0·16 0·005	— —	0·13 0·014
Ceylon	0·43 0·11	— —	0·01 0·0006	— —	0·034 0·007
S. India	0·31 0·15	0·13 0·10	0·013 0·004	0·35 0·15	0·019 0·010
Indonesia	0·77 0·14	0·18 0·02	0·09 0·002	— —	— —

fertility. Owing to relatively high temperatures, destruction of accumulated organic debris from vegetation is rapid, and even forest soils have no great depth of humus-laden profile.

The soils are generally low in base content, and in common with tropical soils in general have small phosphorus contents. Their low base content is reflected in the range of their soil reaction values, which extend from pH 4·5 to pH 6·0. Tea is sensitive to soil reaction, and above the latter figure growth and virility are generally poor. Nitrogen contents are in line with the variable humus status. For the raising of annual crops these soils are demonstrably poor, as was shown in Ceylon during the war, when estates were compelled to raise subsistence crops to fortify the food position; in fact the soils were so unproductive for seasonal crops that the attempt was abandoned. That tea could grow on these soils for so long without fertilizers is attributable to its perennial habit and its elaborate root system.

The summary in Table I gives the range of nutrient content in typical tea soils in India, Ceylon and Indonesia as set out by Mann [22]. The high values for N and P in the Surmah Valley range are attributable to the bheel peat soils. High N in Java is found in some volcanic soils.

The comparatively low nutrient contents of the majority of tea soils might reasonably be regarded as indicative that a general response to all three major nutrients would be evident as soon as systematic manuring was started. This, however, is by no means the case. The indications from the experiments carried out by the research stations are that N in quite liberal quantities will nearly always give a significant response. On the other hand, good responses to P and K are not so uniformly evident. On the old soils of Ceylon, P and K have their definite contribution to make. The South Indian results are similar but less emphatic. In Assam neither of these nutrients gives consistently significant results. In East Africa, where tea cultivation and experimental work are both of more recent date, neither P nor K is productive of responses, although P is very potent on other crops on the same soil. Experience in Nyasaland follows the same pattern.

RESPONSE TO FERTILIZERS

Nitrogen Response

The experimental stations in India, Ceylon and Africa have evaluated empirically the yield responses associated with varying increments of nitrogen. There is no consistency in the scale of increments used except that all the experiments include, or have included, N at rates of 0–80 lb./acre. Within this range the experimental evidence is that the responses are approximately linear. In Table II these data are expressed in the form of a nitrogen efficiency index (response in pounds of crop per pound of nitrogen applied).

From year to year the index varies for a number of reasons, of which the more important are climate and the pruning regime adopted. In regions such as Assam, where there is a winter resting period, it is usual to prune annually. In other localities, though there are usually seasonal periods of dry weather accompanied by a reduction of crop, there is no wintering, and the pruning cycles (i.e. the period between successive pruning operations) extend to as much as six years in some instances. In these circumstances pruning is more severe than in Assam and the bushes have to renew their canopy of foliage before plucking again starts. This may involve a regenerative

TABLE II

NITROGEN EFFICIENCIES IN THE RANGE 0–80 LB. N
(lb. of crop per lb. of N)

Locality	Average	Maximum	Years	Ref.
Assam ..	7·3	8·9	10	[4]
Nyasaland	5·1	7·8	5	[5]
S. India ..	5·0	6·1	12	[20]
Ceylon ..	3·3	6·4	18	[14]
E. Africa ..	2·0	3·2	2	[17]

period of four to six months. The Ceylon experiments show that as time from pruning increases, so does the nitrogen efficiency index [14]. The average values for a series of six three-year pruning cycles are: 1·1 in the first year, 4·0 in the second, and 4·9 in the third. In these experiments fertilizers were applied immediately after pruning, when the bushes were virtually leafless, and thereafter at yearly intervals. Until the tea bush has renewed its maintenance foliage it cannot efficiently use the nutrients applied to it. Lighter pruning reduces the length of the regenerative period and correspondingly diminishes the disparity between responses in successive periods.

At the present time sulphate of ammonia is the dominant type of nitrogenous fertilizer, and the aforesaid efficiencies are based on its use. Blood meal, oil cakes and offal of various kinds have at times been employed. The easy access to these materials from nearby sources is one reason for their use. Other reasons are the well-known mystique concerning "organic" fertilizers and a belief in the value of gradual availability.

Experimental comparisons show that, where the carbon-nitrogen ratio of these materials is low, mineralization is rapid and they behave in a manner similar to sulphate of ammonia, though not quite equalling it in efficiency. A 12-year trial in Ceylon gave the following comparison, none of the differences being statistically significant [12]:

	Yield Index
Sulphate of ammonia	103
Blood meal	98
Groundnut cake	100

As the C/N value increases, responses are less favourable. Bulk manures are a valuable source of nitrogen if they are well made. Experiments have demonstrated that the efficacy of compost prepared on the "Adco" principle is persistent and that when used in conjunction with artificial nitrogen the efficiency of the latter is slightly and significantly enhanced [12]. In the Ceylon experiments the residual effect persisted for 11 years after the liberal application of 60 tons of compost spread over a 4-year period; a smaller effect is attributable to the incorporation of prunings over a similar period [4] (Table III).

A further complicating factor in the response to manures in general, and nitrogen in particular, is the prevalence of shade trees planted in fields of tea. In its natural habitat tea is an undergrowth in *Albizzia* forest. The practice of growing shade trees at a density of about 30 to the acre has many advantages if carefully carried out. Their leaf droppings are a factor in the circulation throughout the tree–soil complex of carbon and mineral nutrients, particularly of trace elements, which is of primary importance. Dense shade, however, inhibits yield and obliterates manurial response. The manner of operation is complicated, since in addition to the effects of shade *qua* shade, other effects, whether competitive or ameliorative, are completely confounded. The Tocklai Station's experiments with artificial shade show the benefits of light shade [9] (Table IV); but an actual field trial with *Albizzia stipulata* spaced 45 ft. triangular

TABLE III

EFFECT OF TEA YIELDS OF BULK ORGANIC RESIDUES IN CONJUNCTION WITH ARTIFICIAL NITROGEN
(Yield in lb./acre after 11 years)

Compost	Artificials		Response	Prunings	Artificials		Response
	Double dose	Single dose			With	Without	
With ..	840	739	101	With ..	866	582	284
Without	729	653	76	Without	653	454	199
Response	111	86	25	Response	213	128	85

TABLE IV

EFFECTS OF ARTIFICIAL SHADE ON YIELDS OF TEA

(4-year means)

Light intensity (%)	Yield	
	lb./acre	%
100	810	100
70	938	116
50	832	109

showed a slightly adverse effect due to the presence of the shade trees [3] (Table V).

The type of tea grown is a relevant factor: not all kinds behave alike. Wight's distinctive agrotypes can be divided into those which respond more freely to shade than to fertilizer, and vice versa. Since commercial fields are mixed in respect of agrotypes, the practical solution is to use both shade and fertilizers.

Potash Response

Response to potash manures varies from region to region and according as the tea is young or old. Mature tea in Assam gives, in individual instances, evidence of both positive and negative response, but the long-term averages are inconclusive [8]. On young tea, however, the response to a range of doses was considerable [26]. Similarly in Ceylon an experiment on young tea demonstrated the efficacy of potash at a very early stage [12]. In the Ceylon trials with mature tea the responses followed a different pattern from that revealed in Assam. Whereas in Assam a small depressive but insignificant effect was recorded after 11 years, in Ceylon after a similar period a null response was rapidly changed to a strikingly positive one by the decline of the plants in the potash-deprived plots. Foliar symptoms developed and deaths of individual bushes ensued. Response was evident with applications as low as 20 lb. K_2O/acre. Between this and the 40 lb. level there was a further less-marked response the significance of which is still in doubt. The data displayed in Table VI are divided into two sets of four 3-year pruning cycles: the first illustrates the generally unresponsive period, the second the responsive phase.

TABLE V

EFFECT OF SHADE TREES ON YIELDS OF TEA, WITH AND WITHOUT NITROGEN

(3-year means, yield in lb./acre)

N	Shade		Response
	With	Without	
With . .	364	421	−57
Without . .	301	293	+ 8
Response . .	63	128	−49

In South India the findings were similar: response after an interim period of eight years and no significant difference between levels of 20 and 40 lb. K/acre at the end of twelve years [20].

The East African experiments, spread over four contrasting regions, are of only short duration, the longest having run for six years. The volcanic soils have generally a higher potash reserve than those of India and Ceylon. None of these trials gives evidence of a potash response.

Phosphate Response

The Ceylon experiments are the only ones that show consistently a positive and significant response to phosphatic manures. P_2O_5 at 30 lb./acre has given a moderate increase in yield which an extra 30 lb. has failed to improve [14]. Low as are the phosphorus contents of typical tea soils, they are generally adequate for the maintenance of the crop at an economic level by virtue of the effectual scavenging operations of the tea root system. As regards the relative merits of superphosphate and mineral phosphates the advantage lies with superphosphates, but it is small—less than 10% according to the Ceylon trials [27].

TABLE VI

RESPONSE OF TEA TO POTASH

(Mean annual yield in lb./acre)

Period	K in lb./acre		
	0	20	40
1930–43 . .	660	661	672
1943–56 . .	614	712	740
Whole period	637	687	706

MAXIMUM YIELDS

The intensification of manuring since the second world war has produced such appreciable yield increments that the question of attainable maxima is being more and more debated.

Heavy dosages have been used in experiments carried out in Assam and Nyasaland. The two nearly comparable series have the following ranges: In Nyasaland 0–240 lb. N with increments of 80 lb.; in Assam 0–200 lb. N proceeding by 40 lb. increments. The Assam tea is on an annual pruning programme; that in Nyasaland has a 3-year cycle. The average yields for three years in both instances are shown in Figure 1 [5, 16].

The curves approach the asymptote at a manurial value of 200 lb. N/acre. The depression in the final Assam yield may be real or the result of experimental error; more will be said about this later. The form of both curves suggests the fitting of exponential regressions. The relevant equation is

$$y_x = y_0 = d(1-10^{-kx})$$

where y_x is the yield in lb./acre corresponding to a nitrogen dressing of x lb.; d is the limiting response $(y_x - y_0)$ estimated for a large value of x; and k is a specific constant. The equations giving the closest fit are

Nyasaland .. $y_x = 1111 + 651(1-10^{-6{\cdot}16\times10^{-3}x})$

Assam .. $y_x = 566 + 1358(1-10^{-4{\cdot}5\times10^{-3}x})$

The Nyasaland curve is a better fit than that for Assam, which is substantially influenced by the final point. The probability that this is a real effect is enhanced by a further experiment in Assam that proceeds by 100 lb. N increments to 400 lb. This experiment showed a very marked decline after the 300 lb. N level. The regression conformed to the quadratic function $y_x = 74{\cdot}6 + 0{\cdot}5x - 0{\cdot}00104x^2$, with a maximum yield occurring at x_{240}. The yield values were not of crop but of new growth removed thrice yearly [1]. The yield depression at high manurial doses suggests secondary reactions in the soil and plant due to concentration as distinct from quantity. Limited though these data are, they show that there are ascertainable ceilings to the response of tea to nitrogenous fertilizers in both theory and practice.

Complementary to the question of achieving maximum yields is the question of the rate of deterioration to be expected if manuring of the crop ceases or is curtailed.

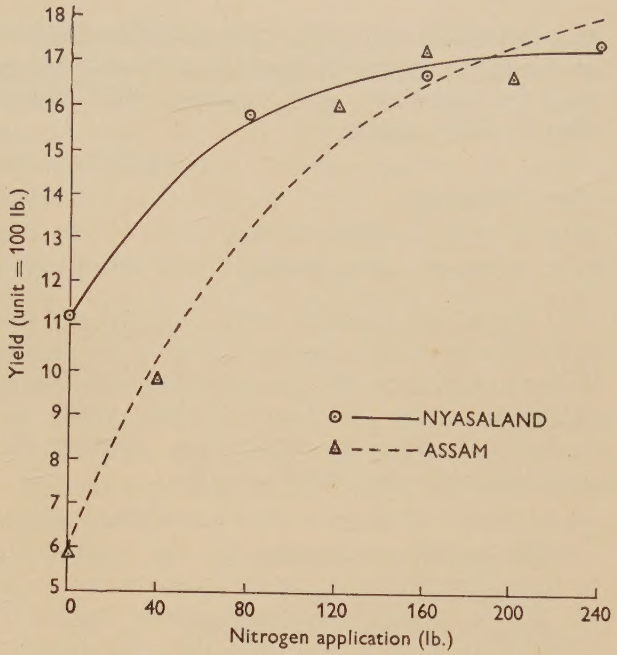


FIG. 1. Nitrogen response in tea: 3-year average

Gokhale [15] has examined this problem in two experimental areas. The first, after receiving 40 lb. N/acre annually for 10 years, was divided: while one half continued under the original manurial regime, the other was left unmanured. The second experiment consisted of two sections, one of which had been given 80 lb. N/acre for 26 years, while the other had been left unmanured. At the end of this period manuring ceased.

In both instances yields of the sections formerly manured deteriorated exponentially. The exponential constant was almost identical in both cases and was independent of rate of manuring, the level of yield attained as a result of manuring, or the type of tea grown. Gokhale concludes that to maintain an established high yield manuring must be continuous [15].

TIME OF FERTILIZER APPLICATION

Experiments to determine the most favourable time for fertilizer application have been carried out in Assam and Nyasaland, where there are well-defined seasonal periods. The cropping period in Assam is from March to October–November. When times of application were evenly spaced at 40-day intervals, starting in mid-February, the following mean yields were obtained over a 5-year period from applications of 40 lb. N/acre [4]:

Date ..	15/2	25/3	8/5	17/6	27/7	Control
Yield .. (lb./acre)	894	933	904	900	865	610

The most noticeable feature was a change in distribution of crop yield during the season. Spring applications made after the growing period was well under way were most satisfactory: late applications were less favourable, followed as they were by dormancy and pruning. Split doses offered no advantage:

	Yield (lb./acre)
120 lb. N March	428
60 lb. N March + 60 lb. N May	422
40 lb. N March + 40 lb. N May + 40 lb. N July	372

In Nyasaland a similar trend is visible in Laycock's figures, which, however, during the course of the experiment did not manifest statistically significant results. He found [6] that yields decreased with delay in applications, whether the doses were split into halves or not:

	Yield index
All applied in November	100
All applied in January	92·8
Half November + half January ..	94·9
Half November + half March ..	89·6

The reality of these differences is given some additional credence by the fact that the regression of yield on effective rain, i.e. that falling after the date of application, was linear and significant. In broad outline, the results suggest that two conditions are necessary for manurial efficiency: first that the plant shall be in vigorous growth, and second that sufficient time should be available for the plant to make use of the applied nutrient before a dormant period, natural or artificial, is imposed on it.

DEVISING MANURIAL SCHEMES

The evidence reviewed points to the outstanding role of nitrogen in producing high yields. Potash stands next in importance, and phosphate last. In present circumstances there is need for further exploration of responses to high nitrogen dosage and to the possible interactions with other fertilizers. There is also need to examine the role of other nutrients, both on the micro- and macro-scale. So far the only well-authenticated example of a minor nutrient deficiency in the field is that of sulphur [25], but the use of sulphate of ammonia satisfies the need for this element.

Field trials are useful guides to fertilizer practice, but they are no more than guides. Variation in soils, climates, cultural practices and age of tea have all to be considered when planning a manurial programme, and consequently the use made of fertilizers will differ much from place to place.

Notwithstanding these reservations, it appears that N applications up to 100 or 120 lb./acre will provide economic responses from tea in good condition. The problem of prescribing for P and K is more difficult. The absence of any consistent interactions in the experiments under review makes the conception of a balanced fertilizer mixture academic; that is, in the sense that there is a vital proportionality in the quantities of the three major nutrients to be used. In the face of this difficulty the only practical method available, where no responses are evident, is to plan doses on the replacement basis. The Nyasaland Tea Research Station advocates this procedure, basing the quantities on the long-term averages of crop production, and criticizes the Ceylon recommendation that quantities of nutrient applied should be proportional to the estimated removal during the previous six months [7]. The objection would appear to be valid, particularly in regions with markedly seasonal cropping periods.

In view of the variation in efficiency of nitrogen at different stages in the pruning cycle it is advisable to delay manuring until the bush has a good canopy of foliage in active growth, and to graduate doses on an incremental basis as the pruning cycle progresses. It is general practice to increase the dosage of fertilizer in accordance with the productive capacity of the field.

There appears to be no indisputable support for frequent applications. Manuring in dry weather is to be avoided, and in seasonal climates the earlier the crop receives its manure the better, always provided that recovery from pruning is well advanced. As a rule equal spacing of applications within the pruning cycle is advisable. Applications made at a time near to pruning are relatively inefficient if the tea needs an extended period during which to recover from the operation.

FERTILIZERS AND SOIL FERTILITY

Because tea is grown as a monoculture, crop rotation is impracticable and other means have to be sought to maintain the soil in good condition. The tea plant itself makes a significant contribution toward this end. Less than half the foliage produced during the course of a pruning cycle is removed as crop, and the rest—the maintenance foliage—is returned to the soil in the prunings. Fertilizers have an important influence on the amount so returned. Cooper [4] showed that the continued incorporation of pruned foliage increased the organic matter and nitrogen content of the soil in comparison with areas from which the prunings were removed. A corresponding though less well controlled increase in carbon and nitrogen was shown in Ceylon by analyses of soils from fields that had been under tea for periods of up to 50 years [13]. In this instance the organic debris from shade trees and green manures also played its part. The volume of organic matter and its contained nutrients thus put into circulation is considerable. The East African Tea Research Station records a leaf fall from *Grevillea robusta* amounting to 6·5 tons dry matter per acre per annum [18].

In effect, what the cycle of manuring, growth and decay does is to link much of the inorganic nitrogen applied as fertilizer with carbon, thus delaying wastage and enhancing the fertility of the soil in which tea and the associated species grow. The soil-improving species, instead of being distributed in the cropping scheme in a time series, as in rotation, are at work together with the exploiting species. Fertilizers benefit both types, and the system seems to offer the most practicable way of providing a stable cultural regime that will not continuously diminish soil fertility.

MANURING IN RELATION TO QUALITY

It is widely believed that the "quality" characteristics of crops are adversely affected by rank growth, and tea is no exception. Leaf plucked in the period of rapid growth that follows pruning makes tea of poorer quality than leaf plucked later in the pruning cycle. The possibility that the rapid growth engendered by the use of fertilizers will depreciate quality cannot be overlooked, but it is by no means easy to arrive at a well-defined generalization concerning the matter. There are formidable difficulties to be overcome in experimental trials. By way of illustration three only may be mentioned. The assessment of quality involves a pronouncedly subjective element. Experimental manufacture designed to eliminate random sources of heterogeneity can never completely correspond to commercial manufacture. Heavy crops produced by fertilizers may lead to a deterioration of the plucking standard, which in itself is the chief determinant of quality; or they may overtax the resources of the factory in respect of machinery, man-power and supervision.

Formal experiments have failed to reveal any quality deterioration when moderate applications of fertilizers are used. The most keenly debated effect is that of nitrogen, but applications up to 80 lb./acre produced no deleterious effects in Ceylon. Chemical estimates of those constituents of the leaves which are presumed to affect quality showed no technologically important change when 40 lb. N/acre was given [11]. In Assam a small depreciation in value was noted when dosage approached 120 lb. N/acre [19]. Nevertheless, the tea trade periodically expresses its opinion that liberal manuring by promoting bumper crops is inimical to the production of tea of the finest quality.

ACKNOWLEDGMENT

The author is grateful to the Statistics Department of Rothamsted Experimental Station for kindly fitting exponential regressions to the data showing nitrogen response in Nyasaland and Assam.

REFERENCES

[1] Barua, D. N. (1956). *Rep. Tocklai Exp. Sta.*, 1955, 34.
[2] Cooper, H. R. (1931). *Quart. J. Indian Tea Ass.*, 1.
[3] Cooper, H. R. (1939). *Manuring Tea in War-time.* Memorandum No. 10, Indian Tea Association, Calcutta.
[4] Cooper, H. R. (1946). *Nitrogen Supply in Tea.* Memorandum No. 6 (3rd edition). Indian Tea Association, Calcutta.
[5] Downie, D. L. and Laycock, D. H. (1954–8). *Rep. Dept. Agric. Nyasald*, 1952–3, 11; 1953–4, 12–13; 1954–5, 9; 1955–6, 16–17; 1956–7, 13–14.
[6] Downie, D. L. and Laycock, D. H. (1956). *Rep. Dept. Agric. Nyasald*, 1954–5, 12.
[7] Downie, D. L., Laycock, D. H. and Cutting, C. V. (1958). *Fertilizers for Nyasaland Tea.* Department of Agriculture, Nyasaland.
[8] Dutta, S. K. (1955). *Rep. Tocklai Exp. Sta.*, 1954, 19.
[9] Dutta, S. K. and Basu, S. (1956). *Rep. Tocklai Exp. Sta.*, 1955, 57.
[10] Eden, T. (1933). *Emp. J. exp. Agric.*, **1**, 297.
[11] Eden, T. (1935). *Emp. J. exp. Agric.*, **3**, 115.
[12] Eden, T. (1949). *Monographs on Tea Culture in Ceylon.* No. 1. Tea Research Institute of Ceylon.
[13] Eden, T. (1951). *J. Soil Sci. Soc.*, **2**, 43.
[14] Eden, T. (1952). *Rep. 13th Internat. Hort. Congr.*, 1138.
[15] Gokhale, N. G. (1955). *Emp. J. exp. Agric.*, **23**, 96.
[16] Gokhale, N. G. (1956). *J. Indian Soil Sci. Soc.*, **4**, 205.
[17] Goodchild, N. A. and Foster-Barham, C. B. (1957–8). *Rep. Tea Res. Inst. E. Afr.*, 1956, 16; 1957, 19.
[18] Goodchild, N. A. and Foster-Barham, C. B. (1958). *Rep. Tea Res. Inst. E. Afr.*, 1957, 17.
[19] Harrison, C. J. (1936). *Experiments on the Quality of Tea.* Indian Tea Association, Calcutta.
[20] Jayaraman, V. and de Jong, P. (1955). *Trop. Agriculture, Trin.*, **32**, 58.
[21] Mann, H. H. (1918). *Memorandum on the Use of Artificial Manures.* Indian Tea Association, Calcutta.
[22] Mann, H. H. (1935). *Tea Soils.* Commonwealth Bureau of Soil Science.
[23] Portsmouth, G. B. (1950). *Tea Quart.*, **21**, 18.
[24] Portsmouth, G. B. (1953). *Tea Quart.*, **24**, 79.
[25] Storey, H. H. and Leach, R. (1933). *Ann. appl. Biol.*, **20**, 23.
[26] Woodford, E. K. and Cooper, H. R. (1941). *Emp. J. exp. Agric.*, **9**, 12.
[27] Visser, T. (1957). *Rep. Tea Res. Inst. Ceylon*, 1956, 39.

THE BRACKEN PROBLEM

E. Conway

(*Department of Botany, University of Glasgow*)

For centuries bracken has robbed the grazier of thousands of acres of land that might otherwise be converted into good permanent pasture. Ploughing is usually impracticable on the moors and hills where the weed is at its worst, and neither cutting nor treatment with contact herbicides has a lasting effect. But good results are now being obtained by foliar spraying with systemic chemicals, and eradication in this way may yet be achieved.

A recent report estimates that some 450,000 acres of rough grazing land in Scotland are now covered with the common bracken fern *Pteridium aquilinum*, and that this includes an increased infestation of 10,000 acres since 1943 [12]. These figures are a challenge to those interested in the care of agricultural land, and while the problem is predominantly a Scottish one large areas in the north of England and in Wales, as well as countries such as Australia and New Zealand, are also much affected by the plant.

The problem is by no means one of recent origin: the Elder Pliny knew of it on Italian hills in the first century, and Walker [17], on his tour through the highlands and islands of Scotland at the end of the eighteenth century, commented on the extent of hill grazing which was covered with bracken and noted, too, that the weed appeared to be spreading. Both writers offered their ideas on ways in which the growth of the plant could be checked.

This article is an attempt to review modern techniques of control; but too often practical measures are undertaken without full appreciation of the real problem—the form and behaviour of the plant—and so it is well, first of all, to examine the outstanding characters of this long-established and troublesome weed.

PLANT FORM

The Stem

If a sample is dug up from a stand of bracken (Figures 6 and 7) the large leaves or fronds that are the familiar part of the plant are seen to arise from a mass of tangled branches. These represent the underground stem or rhizome which acts not only as the expanding axis from which the leaves arise, but as a storage organ which allows the plant to persist through the winter and to renew its growth in subsequent seasons. In its form and extent the rhizome varies very much according to the type of land on which it is growing: in fertile, open soils the branches may penetrate to a depth of two feet, and amounts up to 40 tons to the acre have been dug out from such sites. The branches present a layered form, the frond-bearing ones being mainly in the upper soil levels; there each branch apex initiates one or two fronds each year, and because the interval of annual growth is small the frond-bases are crowded together along the creeping stem (Figure 1(I)). Below these branches thicker, outward-spreading ones with considerable starch reserves penetrate into deeper soil levels (Figure 1(II)). Such branches, which fork only at infrequent intervals and bear very few fronds, are responsible for the outward spread of the plant.

On shallow, less fertile land the rhizome may be compressed into the top few inches of soil, in which case there is little development of deeper branches and the whole becomes a shallow mat of slow-growing stem producing rather small, closely packed fronds. The branches forming this congested tangle fragment by rotting in the older parts, and since any branch apex may function as a new centre of growth (A in Figure 1) the mode of development becomes very confused. Young plants, however, show that the rhizome arises from an embryo by two main axes on which the juvenile leaves are produced (Figure 3). Sometimes these main branches divide, but more often the network comes from secondary buds that are formed at the bases of the leaves (X in Figure 1). While a leaf is active its basal bud usually remains dormant, but as the leaves die the buds develop as subsidiary stems, each growing forward as an axis of indefinite elongation and repeating the development of leaves and basal buds (X in Figure 1). Thus, young plants grown in specially prepared troughs have been seen to produce an underground stem spreading in all directions with a radius as much as six feet in the first year, and giving rise to a massive tangle of rhizome branches by the end of two growing seasons (Figures 4, 5, 12). In the field mature bracken grows much more slowly. Watt

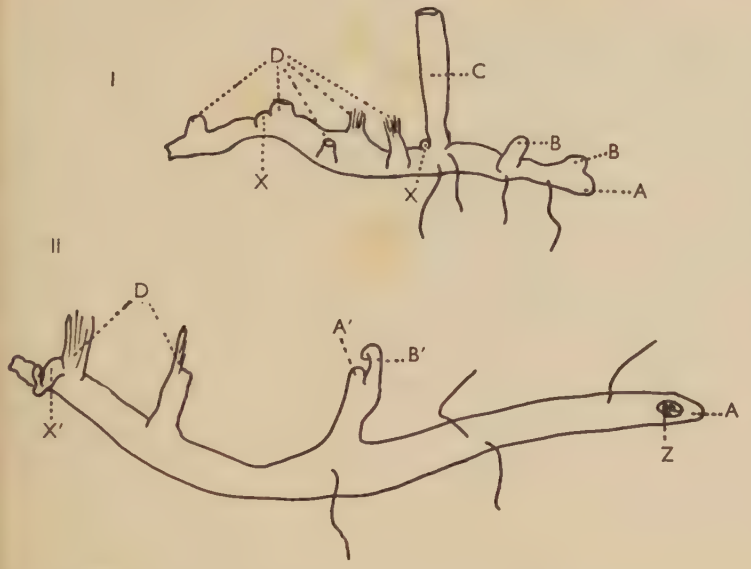


Fig. 1. Rhizome branches dug in September: I from the upper soil levels; II from 6–7 in. below ground level. A = growing points of branches; A′ is the apex of a subsidiary branch. B = frond-buds due to expand in the following season; B′ is a frond-bud on a subsidiary branch. C = current-year frond. D = bases of fronds older than the current year. X = dormant shoot-buds arising abaxially to the frond; X′ is such a bud developing. Z = region of differentiation where a frond-bud or a stem branch may form.

[18], examining rhizome development in the rather uncongenial conditions of the Breckland, suggests that the forward growth of a colony may be little more than three or four inches each year. In the more fertile soils of the West of Scotland, however, axes showing much greater extension have been seen, and the advancing front of a colony may be several feet ahead of the fronds that show above ground.

The Leaves

Development of the frond—the part of the plant that is of immediate concern to the farmer—varies considerably in relation to that of the rhizome. On soils with shallow rhizomes the fronds are likely to be rather sparse and only 8–12 in. high, so that grass can grow quite well and provide some useful grazing. In fact some farmers welcome the presence of sparse bracken, for it tends to raise humidity and temperature and to lower wind velocity and light intensity in the micro-environment. Grass under open bracken cover may be rather more succulent, better protected from frost, and less liable to suffer from the effects of excessive drought. One report [13] suggests that the grazing intensity of swards with light bracken cover may rise in the third quarter of the year, but the herbage is less winter hardy and its stock-carrying capacity drops quickly as cold weather sets in.

Unless growth of the bracken is firmly checked the effect soon shows in deterioration of the sward, and on deep fertile soils the fronds commonly attain a height of 6–9 ft. (there are records of 14 ft.) and form a canopy so dense that ground vegetation is unable to survive; thus, an area below a stand of deep bracken appears quite sterile (Figure 6). Further, the fronds form a blanket of litter when they fade at the end of the growing season and so give extra protection to the underground stem during periods of frost and unfavourable weather; in this way they allow growth of the stem to continue late into the autumn and to start early in the following spring, thus extending the period of development.

It must be borne in mind that the leaves are ephemeral organs: they are easily removed, and

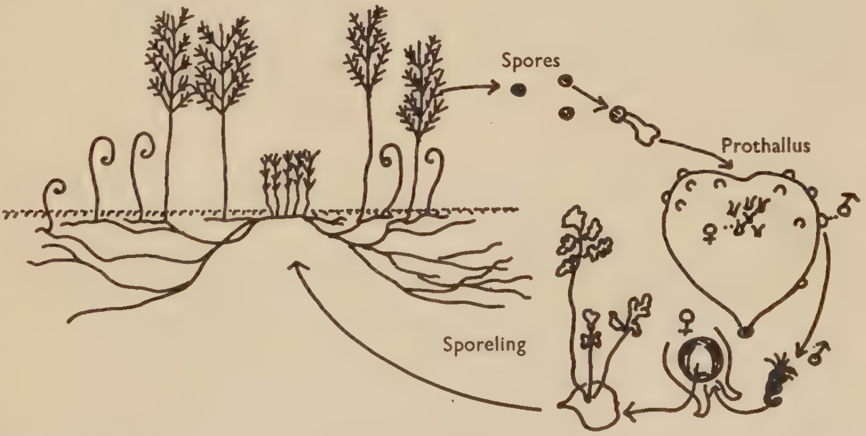


Fig. 2. Life-cycle of the bracken plant. The diagram shows the general form of a developing plant with its branching underground stem from which the leaves arise. On the undersides of the leaves spores form in the late summer and are scattered by wind dispersal. Under suitable conditions they grow into small, sexual plants (prothalli) which bear the reproductive cells. After fertilization the young sporeling grows for a time still attached to the prothallus; but it becomes independent as leaves and roots are established. In this diagram no account is taken of relative sizes: a mature frond may be 6–8 ft. high; a prothallus is less than ½ in. across.

each one lasts only for one year. It is the underground stem, hidden and well protected against temperature and desiccation changes, that presents the real problem.

Reproduction

Spread of bracken comes very largely from increased growth and outward extension of the rhizome branches of an established colony: it is a vegetative increase. Really heavy stands show how deeply entrenched the plant may be and emphasize that the infestation may be the result of long periods of growth in the same area.

Entirely new colonies, however, arise in a completely different way (Figure 2). Reproductive spores are formed on the undersides of mature fronds and are dispersed by wind or other agencies late in the summer. Since bracken is a fern, the spores do not give rise directly to new bracken plants but germinate to form small, flat, green plants less than the size of a sixpenny piece. These prothalli are a phase in the life-cycle of the plant, and on them arise the sexual reproductive organs. By the fusion of two gametes the embryo is initiated in direct contact with the parent prothallus, and only when the sporeling has produced several leaves and can function as an independent photosynthetic unit does the prothallus shrivel and fall away. At first the embryo plants have small, simple leaves, and these remain soft and delicate during the first growing season: it is not until late in the second or in the third season that a plant shows the tough, much-divided leaf of field bracken.

Although the spores are formed in prodigious numbers and develop readily in laboratory culture, prothalli and young sporelings are seldom found in the wild [4]. It seems likely that the spores and prothalli are vulnerable phases of the life-cycle [5]: both are eaten by soil insects and attacked by soil fungi; they are quite incapable of withstanding frost or desiccation by wind or sun; and in regions such as Scotland with an early onset of winter the spores are often shed so late that there is not time for the young plants to acquire any degree of protection before they are overtaken by conditions too rigorous for their survival. Only on the rubble dumps of cities "blitzed" during the 1939–45 war have bracken prothalli and sporelings been found in any number, for here, when free water was available, they found highly favourable conditions for their growth in the open rather alkaline medium with little competition from other organisms. For the most part, in the field, prothalli that survive and give rise to embryos do so in well-protected places, such as rock crevices, under bushes and along hedgerows; and not until an established and actively growing plant has emerged is the new infection seen. By that time it may be a strongly entrenched centre of growth, capable of forming a definite invasion within a very few years.

Such new invasions, however, are rare. It is generally accepted that, in Britain, spores do not play an important part in disseminating the plant, and that vegetative increase from existing colonies is the main way in which bracken spreads. This underlines the need for attack on the underground stem rather than on the leaves when measures for control are undertaken.

MECHANICAL METHODS OF CONTROL

Until very recently all control depended on mechanical treatment of the plant. Ploughing has long been accepted as the basic mode of treatment; but although fragmentation and exposure of the rhizome branches will kill the plant, this implies ploughing at a time when the stem fragments can be destroyed. Autumn ploughing and exposure to winter frosts is usually effective; spring ploughing may simply scatter the pieces of stem and create numerous new growth-centres—a condition seen recently on a newly ploughed field in Devon, where every furrow in the late spring showed a crest of actively expanding young bracken fronds.

In many places, however, ploughing is impracticable either because of the slope or rocky nature of the land, or because the bracken is spreading out from a bank or hedgerow. Ever since the photosynthetic activity of green leaves has been understood, the concept of treating areas of this kind has been that if the leaves are removed no food can be passed down to the underground stem, so that this organ will be starved and die. For many years, therefore, methods and machines for removing the functional leaves or destroying their activity have been developed. There can be no doubt that such treatment checks the rate of development of the plant and may, if the rhizome mass is slight, lead to the death of the underground stem. Most farmers find that after three or four years of regular cutting bracken is so reduced that it hardly interferes with the usefulness of grazing land; but the amount of stored food in an extensive rhizome is much greater than has been generally recognized, and the underground stem is not killed. Growth continues slowly and, if cutting is discontinued, fronds appear above the ground again and

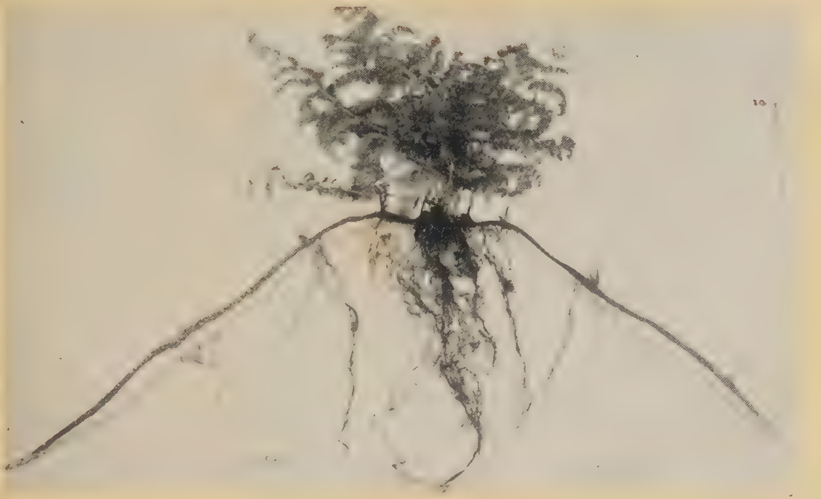


FIG. 3. Developing sporeling of bracken: mid-season of the first year.

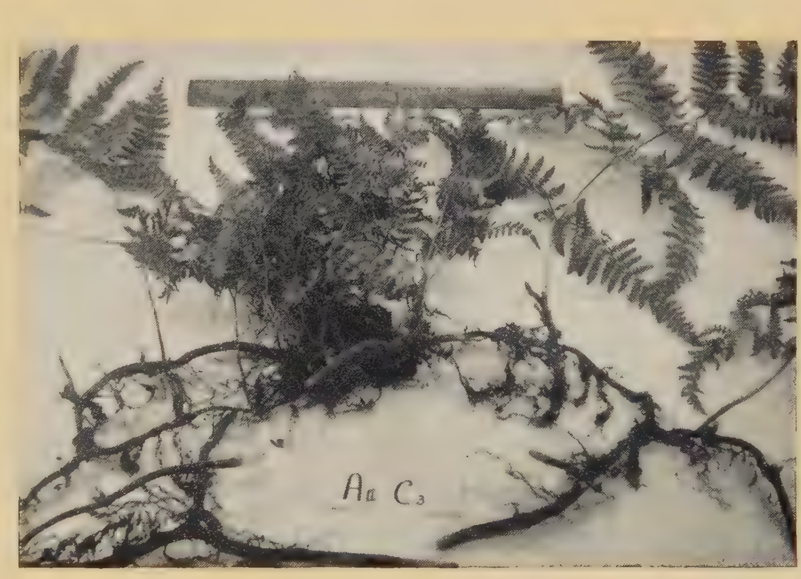


FIG. 4. Developing sporeling of bracken: end of the first season.

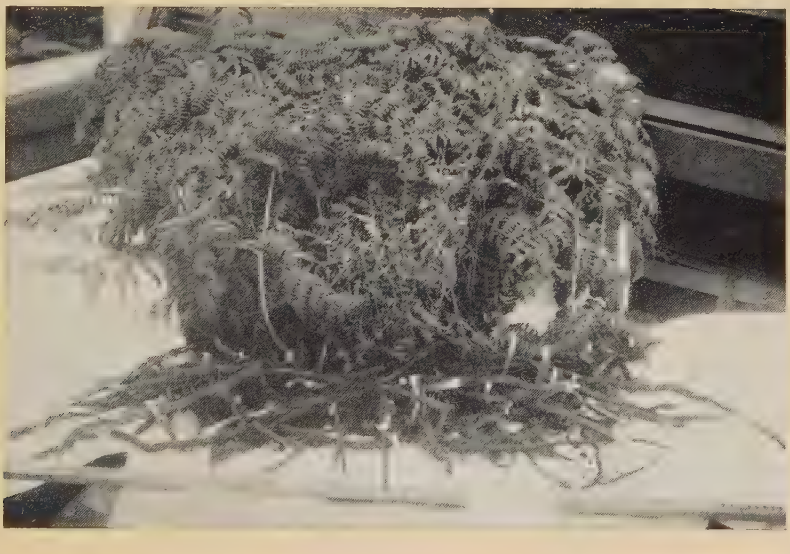


FIG. 5. Developing sporeling of bracken: end of the second season.

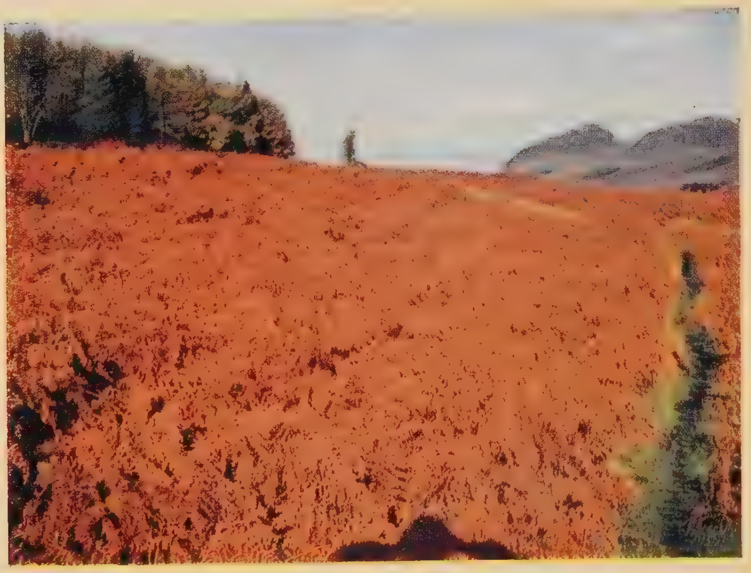


FIG. 6. A Dunbartonshire hill-grazing, showing the complete dominance of bracken.

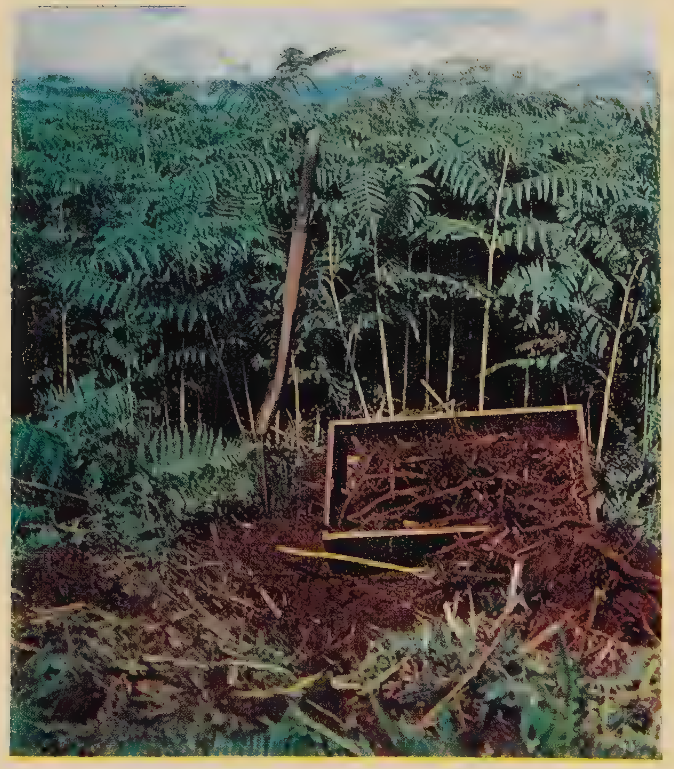


FIG. 7. A stand of bracken on a Dunbartonshire moor. When dug up, the underground stem is seen as a tangled mass of branches forming a mat in the upper soil layers. The large fronds arise near the growing tips of the branches.

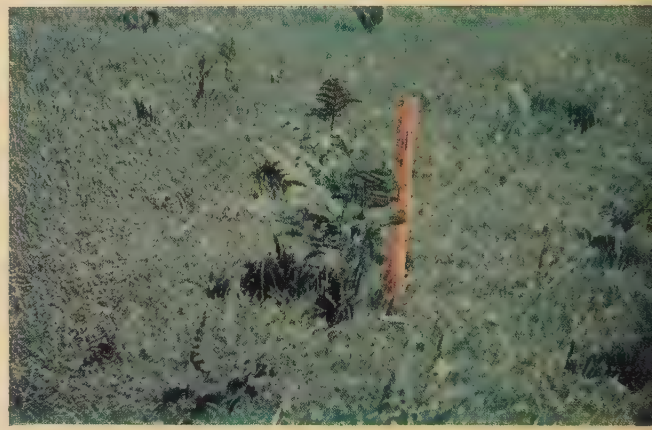
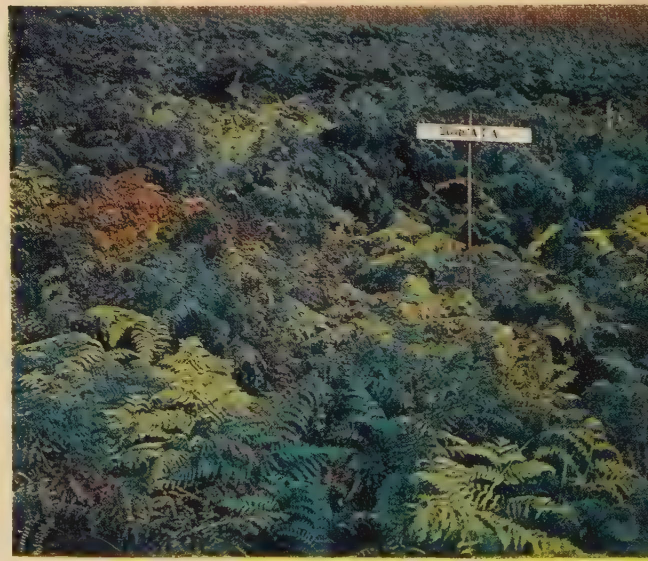


FIG. 8. An Argyllshire hill-grazing which had been cut each year for 5 years and then left untouched for 2 years. Numerous small bracken fronds show the degree of re-establishment.

FIG. 9 (right). Frond development on an area of bracken sprayed with amino-triazole in the previous year. The chlorotic condition of the new fronds shows that the compound was translocated through the plant and has affected the extent of chlorophyll development in the new season.



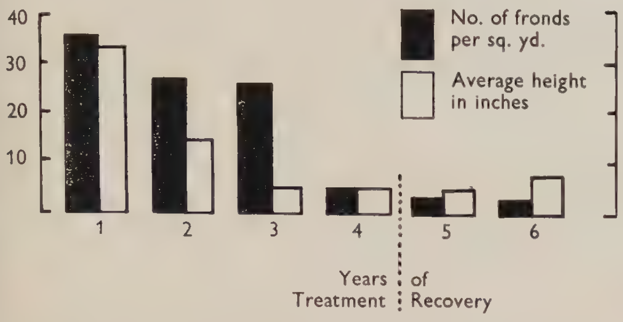


FIG. 10. The effects of cutting on height and density of bracken. Experimental plots were cut twice a year (late June and late July) for three years, once (July) in the fourth year, and left untouched for the fifth and sixth years. Data were collected in late June each year. (From West of Scotland Agricultural College Report No. 24, 1958.)

soon re-establish the colony. Figure 8 shows an area of grazing land in Argyll where bracken 3–4 ft. high had been regularly cut for five years and left untreated for two: a good sward with little sign of any remaining bracken was obtained and grazed by sheep, but by the end of the second summer after cutting had been discontinued large numbers of small fronds had appeared all over the ground. Each frond was a potential growth-centre, capable of forming an area of consolidation within a very short time.

A similar example of regeneration is shown in Figure 10, which refers to the findings of a series of trials carried out in West Perthshire during the period 1952–7 [14]. Regular cutting for three years had reduced the number and height of fronds on the trial plots by more than 80%, but by the second season after treatment had ceased the plants were recovering. This increase will inevitably grow progressively greater, so that complete recovery is to be expected within a few years.

An explanation of the mode of recovery is provided by data obtained from another trial, the results of which are illustrated in Figure 11 [7]. In this experiment the results of cutting were analysed by comparing the number of expanded fronds on measured plots with the number of frond-buds laid down on the rhizome. This showed that the fronds which expand on treated areas during the first few years of cutting come from a large reserve of frond-buds that are always found on the underground stem and seem to be a feature of the plant. Although the reserve of frond-buds was largely depleted after three years of frond removal the food stored in the rhizome was not exhausted, and on the undisturbed underground stem numerous frond-bud initials were laid down. These would remain hidden below ground for one or two years; but eventually they would expand and reach the surface, and each would then become an active centre of further growth. This feature can only be appreciated by direct observation of the underground stem.

By experiments such as these it has come to be realized that, in dealing with well-established stands, frond removal by cutting or any other method simply slows down and checks growth: it acts as a means of control but seldom of eradication, and unless constantly renewed the labour of years may be entirely wasted.

CONTROL BY HERBICIDES

Trials of the effects of various chemical substances on bracken have been occasionally reported for more than 25 years [2]. At first sulphuric acid and other chemical compounds were used as defoliants in areas where mechanical treatment

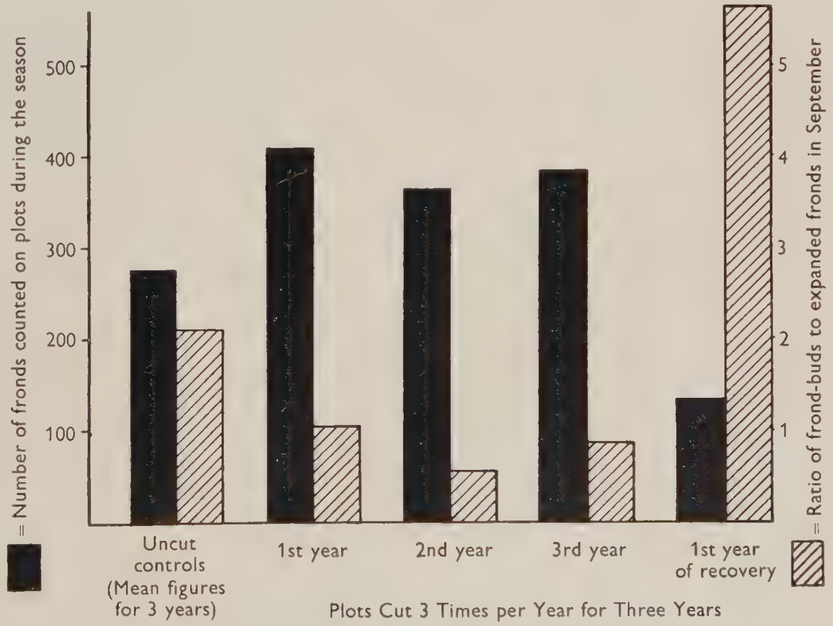


FIG. 11. The relationship, seen during the three years of a cutting experiment and the first year of recovery, of the expanded fronds showing on experimental plots and the hidden reserve of frond-buds. (From N.A.A.S. Quarterly Review No. 25, 1954, by permission of the Controller of H.M. Stationery Office.)

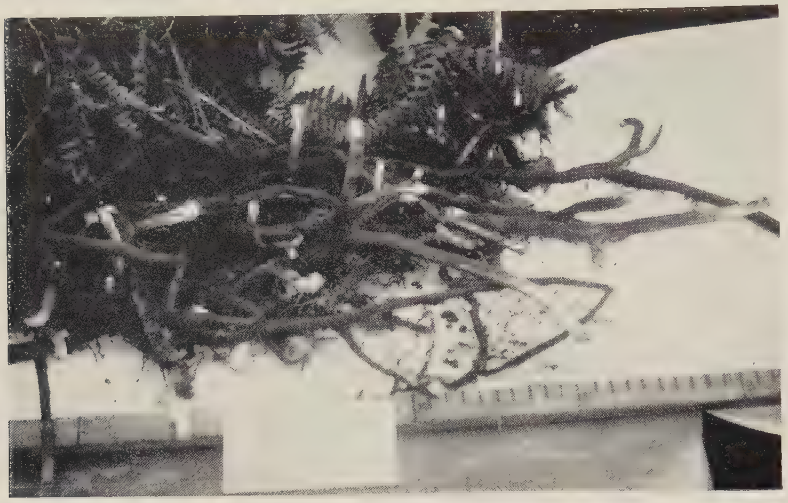


FIG. 12. Rhizome branches of the plant shown in Fig. 5. The active condition of the tips of the stem branches and of the frond-buds is noticeable.

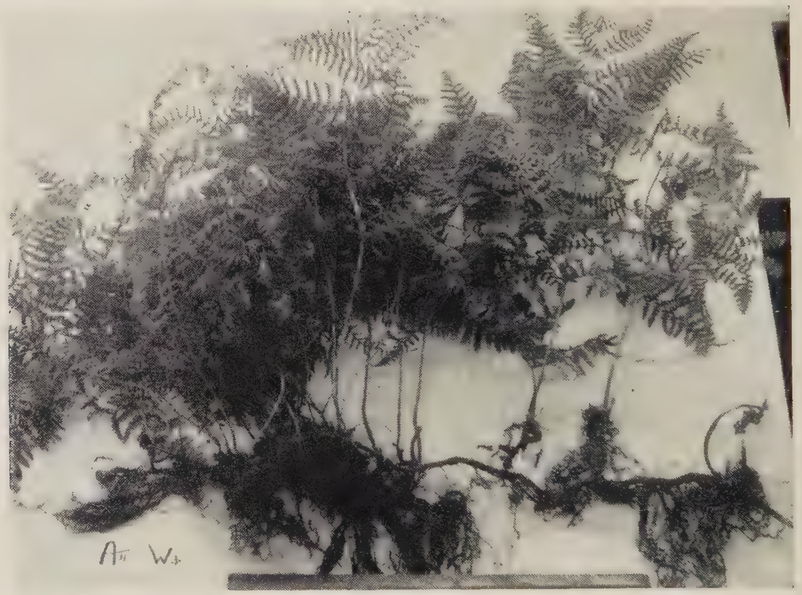


FIG. 13. First-year sporeling in September 7 weeks after frondular spraying with 1000 p.p.m. of 2,4,5-T. The control, untreated plant for this experiment is the one shown in Fig. 4.

was difficult, but the method was expensive and the results were unconvincing, so that little progress was made. With the increase in the number of proved herbicides during the past decade, and particularly with the coming of translocated herbicides, much greater interest has been taken in their use on bracken. During the past four years a considerable number of screening tests have been made using both toxic contact chemicals and translocated hormone-type substances [8, 9]. As this work is still actively in progress, the present report is offered only as an interim one.

With the use of chemical herbicides, problems of evaluation of the effects have arisen. The ultimate test to the agriculturist is the extent to which leaves develop on the land in the years after treatment, but this takes a long time to determine and gives little idea of the effects produced on the vital organ—the underground stem. A method of evaluation has therefore been devised using the state of the layered branches dug out from sample areas [9] (Figure 1). In this way analysis of the effects of any treatment may now be based on (*a*) frond counts to record reduction in frond height and density, and (*b*) rhizome sampling to record the state of the stem-tips and the frond-buds.

General Herbicides

Tests with contact toxic substances applied to the rhizome through the soil or on to the fronds have not given any satisfactory degree of control. Table I shows the results of a series of trials carried out in 1957.

TABLE I

EFFECT OF SOME CONTACT HERBICIDES ON BRACKEN

Treatment	Foliage condition in early September	Rhizome percentage dead or dying in mid–late September		
		Apices of upper branches	Frond-buds on upper branches	Deeper branches
Control	Full green	Nil	10	10
Sodium chlorate (pre-emergence) 170 lb./acre	All dead	100	100	70
Sodium chlorate (foliar spray, 6/8/57) 20 lb./acre	All dead	5	60	50
Ammonium sulphamate (pre-emergence) 75 lb./acre	Scattered, not very vigorous	10	Nil	20
Ammonium sulphamate (foliar spray, 11/6/57) 15 lb./acre	Partially scorched; some recovering	Nil	40	20
Borate (granulated) (pre-emergence) 300 lb./acre	Dead or emaciated; pale green	100	100	60
Para-chlor-benzoic acid (pre-emergence) 10 lb./acre	Little effect visible	Nil	Nil	Nil

Heavy doses of sodium chlorate and borates killed all bracken rhizome in the top 3–4 in. as well as all other vegetation. The latter point is, of course, a big disadvantage, even though the chemicals were found to be leached completely from the damp peaty soils of the test area within 5 months. But in spite of such top soil sterilization the deeper rhizomes were found to be completely healthy five months after heavy spring treatment. The supposition must be, therefore, that though these areas would appear to be free of bracken for some years they would soon be colonized again, and during that time expensive reseeding would be needed to allow the land to be used at all. The other two chemicals tested, ammonium sulphamate and para-chlor-benzoic acid, were of little use as soil sterilants; ammonium sulphamate is, however, a rapid and effective defoliant.

The form of the plant, then, with its deep-running stem that provides protection from the effects of toxic substances, forces the conclusion that contact herbicides are of little use against bracken, except possibly to kill out small pockets that call for "mopping up" in such awkward places as against walls, around fences, or in crevices from which the plant might be liable to spread outwards.

Translocated Herbicides

With the recognition of the herbicidal activity of synthetic growth-regulating compounds such as MCPA and 2,4-D there have been periodic inconclusive reports of their use on bracken [3, 8, 16]. In 1955–6 a series of tests was made by spraying MCPA, 2,4-D, 2,4,5-T and 4-CPA on young first-year plants growing under garden conditions. It then became clear that growth-regulating compounds were able to induce systemic effects after foliar spraying, proving that translocation could take place into an active rhizome (Figure 12) [8]. At first no such effects were seen with tests on field bracken; but later, using the analysis of direct observation on the state of the apical organs, translocation by substituted phenoxy-compounds and other growth-regulating substances has been traced. The following descriptions are given to illustrate effects that have been found after treatment with a few representatives of these compounds.

Amino-triazole (ATA) is readily translocated by bracken [9]. Field trials carried out late in June 1957 showed scorching and death of the fronds within a few days, and the fronds emerging on the same plots in the spring of 1958 were markedly chlorotic (Figure 9). Many of these young fronds showed brown, scorched patches on their lower segments, and these gradually spread until the fronds withered after only a short time above ground. Other vegetation on the trial plots (e.g. *Luzula sylvatica*, *Viola canina*, *Holcus mollis*,

TABLE II

EFFECT OF AMINO-TRIAZOLE AND DALAPON ON RHIZOME TIPS AND ASSOCIATED FROND-BUDS OF BRACKEN ANALYSED (A) 8 WEEKS AND (B) 1 YEAR AFTER TREATMENT

Treatment	Fronds of Current Year					Fronds older than 1 year				
	Rhizome (20 tips)		Frond-buds			Rhizome (10 tips)		Frond-buds		
	Healthy	Dead or dying	Healthy	Dead or dying	Not visible	Healthy	Dead or dying	Healthy	Dead or dying	Not visible
(A) Control	20	—	16	1	3	10	—	6	—	4
ATA 20 lb./acre ..	20	—	13	—	7	10	—	9	—	4
ATA 40 lb./acre ..	19	1	10	1	10	9	1	6	—	4
Dalapon 20 lb./acre ..	20	—	10	—	10	10	—	4	—	6
Dalapon 40 lb./acre ..	19	1	15	—	5	10	—	3	—	7
(B) Control	20	—	16	—	4	11	—	5	1	4
ATA 20 lb./acre ..	19	1	16	—	6	10	—	9	1	1
ATA 40 lb./acre ..	20	—	18	—	6	9	1	6	—	4
Dalapon 20 lb./acre ..	18	2	16	—	6	10	—	8	1	1
Dalapon 40 lb./acre ..	17	3	15	—	8	9	1	6	1	3

Agrostis stolonifera) also showed chlorosis. Later in the season unaffected fronds appeared on the treated plots. Analyses of the state of the rhizome were made eight weeks and one year after treatment (Table II), and little effect was visible at either time on stem apices or their associated frond-buds. It would seem, therefore, that the frond-buds laid down at the time of spraying had their chlorophyll-producing mechanism affected; but few other effects could be ascribed to treatment with ATA.

Dalapon (2,2-dichloropropionic acid) has been extensively tested [9, 10, 11, 15]. In two series of tests, one carried out near Oxford by the Agricultural Research Council's Unit of Experimental Agronomy and the other in the West of Scotland by the West of Scotland College of Agriculture, frond expansion was retarded in the year after treatment. This effect was marked early in the season, but it lessened considerably as the season progressed.

Rhizome analyses taken eight weeks and one year after treatment failed to show deterioration of the underground stem (Table II), though anatomical investigations revealed a marked increase of sclerotic tissues in the apical parts of the branch tips. These tissues may have played a part in slowing down the rate of expansion of the fronds. Dalapon, then, appears to offer a method of retarding development but not of causing any permanent damage to the rhizome or frond-buds.

Gibberellic acid has been tested only on first-year plants under greenhouse and garden conditions. The effects produced were those of general stimulation of growth, particularly on the main axes of the leaves. Early sporing took place on garden plants treated with doses of 500 p.p.m., but similar effects have been seen after treatment with other compounds.

The first substituted phenoxy-compounds found to be readily absorbed and translocated through the actively developing tissues of young plants were the phenoxyacetic acids MCPA, 2,4-D, 2,4,5-T, 4-CPA and their butyric homologues. These were found to reduce, harden and twist the

TABLE III

EFFECT OF AMINO-TRIAZOLE AND DALAPON ON FROND DENSITY IN THE YEAR AFTER TREATMENT

Treatment	Reduction in density (%)		
	June	July	August
ATA:			
20 lb./acre	75	52	18
40 lb./acre	92	78	10
Dalapon:			
20 lb./acre	76	48	26
40 lb./acre	90	68	15

tissues of expanding frond-buds and to reduce the extent of rhizome development, producing contortion and marked dormancy or drying out of the rhizome apices [6, 8] (Figure 13). Later tests on two- to three-year-old plants and on field bracken show that after foliar spraying a number of substituted phenoxy-compounds are readily translocated into meristematic tissues adjacent to a sprayed frond, and that deformation and twisting of the rhizome apical tissues occurs which may lead to a breakdown of the outer tissues with subsequent rotting of the organs concerned.

Reactions of this nature suggest a more direct form of attack on the underground stem than is possible with most other forms of treatment, though more investigation is needed before the action of these compounds can be regarded as completely effective in control. Systemic effects seen so far have been in the main on organs apical to treated fronds, and only for some 10 in. basally along the rhizome. This may mean that secondary branches away from an expanded frond remain unaffected after treatment, and these could give rise to new centres of growth. Further, effects have been observed only on active meristematic tissues, and little is yet known of the effect of treatment on the large reserve of dormant stem and frond-buds which seems to be a permanent feature of the plant.

Until these and other questions can be answered, the efficiency of the translocated, substituted phenoxy-compounds cannot be completely assessed. But an approach more hopeful than earlier ones is offered in the fact that such compounds give a mode of direct attack on the underground stem which, by virtue of its form and position, has for so long remained impregnable.

It is almost certain that the range of translocated herbicides will widen considerably in the near future and that some may prove to be selective towards bracken. Many technical features remain to be considered—cost, rate and time of application, and mode of application are only a few of them—and all must be brought into line before chemical treatment of such an entrenched weed as bracken can take its place in an agricultural system. Nevertheless, the fact that chemical substances capable of being carried through the plant and acting as agents of destruction on the centres of growth and development are now known, opens a new approach to this age-old problem.

ACKNOWLEDGMENT

The author is indebted to Mr. J. D. Forrest for permission to use the colour photographs reproduced in Figures 7 and 9, and for the information used in compiling Tables II and III.

REFERENCES

[1] Braid, K. W. (1935). *Scot. J. Agric.*, **18**, 121.
[2] Braid, K. W. (1937). *Agric. Progr.*, **14**, 29.
[3] Braid, K. W. (1947). *J. Brit. Grassl. Soc.*, **2**, 181.
[4] Conway, E. (1949). *Proc. roy. Soc. Edinb.*, **53**, 325.
[5] Conway, E. (1953). *J. Ecol.*, **41**, 289.
[6] Conway, E. (1956). *Nature, Lond.*, **177**, 1088.
[7] Conway, E. and Stephens, R. (1954). *N.A.A.S. Quart. Rev.*, No. 25, 1.
[8] Conway, E. and Forrest, J. D. (1956). *Proc. 3rd Brit. Weed Control Conf.*, 255.
[9] Conway, E. and Forrest, J. D. (1959). *Proc. 4th Brit. Weed Control Conf.* (In the press.)
[10] Fryer, J. D., Chancellor, R. J. and Evans, S. A. (1959). *Proc. 4th Brit. Weed Control Conf.* (In the press.)
[11] Fryer, J. D. (1959). *Down to Earth*, **14**, No. 4, 1.
[12] Hendry, G. F. (1958). *Scot. Agric. Econ.*, **9**, 25.
[13] McCreath, J. B. and Martin, D. J. (1954). *Rep. W. Scot. Coll. Agric.*, No. 15.
[14] McCreath, J. B. and Forrest, J. D. (1958). *Rep. W. Scot. Coll. Agric.*, No. 24.
[15] Rohrig, E. (1958). *Allg. Forstz.*, **13**, 268.
[16] Stephens, R. (1953). *Proc. 1st Brit. Weed Control Conf.*, 249.
[17] Walker, J. (1808). *Economical History of the Hebrides and Highlands.*
[18] Watt, A. S. (1940). *New Phytol.*, **39**, 401.

SEED TREATMENT OF COTTON AGAINST DISEASES AND INSECT PESTS

S. A. J. Tarr

(*Botany Department, University of Exeter*)

Research on the seed dressing of cotton has been highly rewarding. All the main cotton-growing countries are steadily developing the techniques that best meet their particular requirements, and seed-borne diseases that once took a heavy toll of the crop are now being well controlled. Insecticidal seed treatment is also proving to be of value, and it may yet be possible to safeguard the plant in its early stages from both pests and pathogens.

During recent years treatment of cotton seed used for sowing has become a standard agricultural practice in many countries where the crop is cultivated on a large scale. At first treatment was concerned largely with destruction of seed-borne pathogens, but increasing attention is now being directed to its use as a method of improving seed germination and emergence, thus promoting the vigorous early growth, even stands and optimum plant populations conducive to high yields. A recent development, still in the experimental stage, is the incorporation of insecticide into the seed dressing with the aim of protecting the seed, seedling, and young plant against certain soil-borne and air-borne insect pests; with this might be combined protection of stored seed from attack by storage pests.

CROP LOSSES

A recent estimate [14], based on data submitted in response to a questionnaire, suggests that diseases cause some 27·8% loss to cotton in British Colonies (mostly in Africa), a percentage loss exceeded only by cacao (29·4%). This represents a "lost" area of nearly a million acres, and it may be that insect pests cause losses of about the same order. Persons familiar with the severe disease and pest attack which cotton not infrequently suffers in parts of Africa will probably consider an estimate of 30% overall crop loss to be a conservative one. Control of cotton diseases and pests is highly developed in the United States and crop losses are correspondingly less; thus a recent survey [22] attributes 12% crop loss to diseases in 1957, and, despite extensive spraying, it is estimated that insect pests still take one bale of cotton in seven [3]. Although precise data are lacking, it seems reasonable to suppose that overall crop losses of at least 20–30% are caused by diseases and pests to cotton grown in India, Pakistan, China, the Soviet Union and other parts of Asia.

Of the diseases responsible for these heavy crop losses bacterial blight is without doubt the principal one in the case of rain-grown cotton in Africa and Asia, and epiphytotics of this disease can cause widespread devastation. In the Sudan during the 1954–55 season severe but fortunately localized outbreaks of blight caused about 20% crop loss over some 4000 acres of cotton in the Gezira, and the total loss throughout the 200,000 acres probably amounted to at least 10,000 bales (each 500 lb.) of lint, worth about £750,000. Several factors combine to make the Sudan Gezira a very favourable place for the disease, and prior to thorough application of control measures, particularly seed treatment and crop sanitation, severe epiphytotics sometimes caused crop losses heavy enough to constitute a serious threat to the economic well-being of the country. In Uganda, before control measures were put into operation, the disease was estimated to cause crop losses amounting to several million pounds sterling in some years, and there is a growing realization of the serious damage it can cause to cotton wherever cultivated as a rain-grown crop. Bacterial blight is seed transmitted, and seed treatment is perhaps the most important single control measure used in combating it; hence it is considered in some detail in the following section.

BACTERIAL BLIGHT

Bacterial blight, also known as angular leaf spot, blackarm and bacterial boll rot (gummosis), is caused by the bacterium *Xanthomonas* (*Bacterium*) *malvacearum*. Being favoured by warm, wet climatic conditions and spread largely by rain, it is of no economic importance in such countries as Aden and Egypt, where cotton is grown as a ground-irrigated crop under rainless condition; it might, however, be favoured by overhead irrigation. First symptoms are angular leaf spots, translucent and water-soaked in appearance but later turning black and tending to spread along the veins (Figures 2–3). This can cause considerable leaf shedding and is often followed by lesions on the stems (blackarm) and on the bolls. Severely attacked seedlings may be killed, while older plants suffer extensive leaf shedding and may break at stem lesions. Infected bolls may rot and yield only a small amount of stained lint. Thus under favourable conditions the disease can severely damage the plant at all stages of development (Figure 1)

Control measures are directed towards minimizing sources of infection for the newly sown crop. These sources are twofold: infected cotton debris (twigs, leaves, bolls) which remains on the fields at the end of the season, and seed-borne infection. The practical significance of infected debris in disease carry-over varies with agricultural and climatic conditions. In the Gezira such debris survives the hot, mostly dry, intercrop months and is a potent source of infection which must be eliminated; this is enhanced by the flat featureless nature of the intensively cultivated land, by the virtual absence of natural vegetation during the dry intercrop months, and by the windstorms which pick up and scatter debris. Elsewhere, however, it may be of less importance, as probably in Uganda, where some rotting of debris or reduction of its infectivity is thought to be brought about by the considerable rain which falls during the intercrop months; rain also produces a dense cover of natural vegetation tending to restrict dissemination of infection from debris that survives, especially when the crop is grown in small scattered fields rather than intensively. Further investigation of this possibility is needed, and in areas with very wet intercrop months it may be found that seed treatment alone will give adequate control of bacterial blight, especially if wide crop rotations are practised and the current season's cotton fields are situated as far distant as possible from those of the previous season. Bacterial blight is confined largely to cotton, and wild plants are not known to play any part in its seasonal carry-over. Restricting its spread by spraying or dusting infected fields with bactericides has yet to be investigated; quite rightly attention has been concentrated on preventing the disease getting into the crop.

Although blight-resistant varieties of cotton have been bred, *X. malvacearum* is a variable organism probably existing as numerous strains, and new races of slightly different pathogenic potentialities are no doubt evolving. Some of these may be able to infect hitherto resistant cottons, and the likelihood of this happening will be reduced by control measures that destroy the bacteria. This will hold good until the disease is eradicated by exclusive cultivation of blight-immune varieties, an objective unlikely ever to be completely achieved. With these considerations in mind it is clear that cotton seed treatment is to be recommended as standard procedure wherever the disease is of importance.

PROBLEMS OF SEED TREATMENT

Seed of cultivated cottons usually bears short white or brownish-green hairs ("fuzz") firmly attached to the seed coat, and also long thickened white fibres (the lint or raw cotton of commerce) which are removed by a mechanical process known as ginning. Seed of American upland cottons (*Gossypium hirsutum*, mainly rain-grown) usually has a conspicuous fuzz covering most of the seed coat, whereas that of Egyptian-type cottons (*G. barbadense*, mainly irrigated crops in Egypt and the Sudan) has a small tuft of fuzz at one end. Seed coat, fuzz, and the small amount of lint usually remaining after ginning can all carry blight bacteria and must be effectively disinfected in seed treatment. This hairiness can be reduced by passing the ginned seed through a delinting machine (reginning), and can be entirely removed by acid-delinting with concentrated sulphuric acid. Acid-delinting is commonly practised in the United States, but the danger and expense make it at present impracticable for large quantities of seed in most parts of Africa and Asia.

A further complicating factor, about which little is known, is the possible presence of blight bacteria *inside* the seed; destruction of these, if indeed possible without injuring the seed, would necessitate special methods, such as accurately controlled heat treatment. Fortunately available evidence suggests that internal infection is generally slight, perhaps occasionally occurring in very heavily infected seed of highly susceptible cottons, or when seed cotton in open bolls in the field is thoroughly wetted by rain. Entrance of blight bacteria through the micropyle or through the seed coat at the chalazal end has been reported in the United States [18, 29], where it has also been shown that acid-delinted seeds immersed in bacterial suspension for three hours swell sufficiently to allow entrance of the bacteria [30]. It is possible that internal infection might be reduced by liquid seed treatment or by slightly volatile powder bactericides such as organo-mercurial seed dressings. In the Sudan a very small amount of infection usually remained after steeping heavily infected cotton seed for two hours or longer in 0·2% mercuric chloride-iodide solution, which is one of the most potent disinfecting agents known, and even acid-delinted seed similarly steeped produced 0·17% infected seedlings when planted out. It is difficult to resist the conclusion that a small amount of internal infection can occur, but present evidence suggests that the bacteria are predominantly localized on the seed coat and only occasionally within the seed.

Efficient mercurial seed dressings often give 100% protection when applied to lightly infected seed, but this is rarely obtained with heavy seed-borne infection. The amount of this residual infection tolerable under field conditions varies in different countries, and is likely to be small where agricultural and environmental factors favour rapid spread of the disease to epiphytotic proportions. The Sudan Gezira is such a region, and a further aggravating factor is the heavy seed rate used, often resulting in considerably more than 100,000 seedlings per acre. This is in part unavoidable, for about ten emerging seedlings per sowing hole are often necessary to break through the hard surface crust that forms after irrigation and subsequent drying out of the heavy clay surface soil. With such high seedling populations even a small increase in efficiency of seed disinfection is likely to be of appreciable practical value. A residual infection of only 0·1% would produce about 100 infected plants to the acre, probably scattered throughout the field and able to initiate severe outbreaks of the disease; it has been computed [32] that with cotton at 3 ft. by 1 ft. spacing no plant would be further than about 12 ft. from an infection focus. This degree of control would not be permissible in the Gezira, although perhaps acceptable in places less favourable to the disease. In consequence seed treatment for control of bacterial blight has to be very efficient indeed in some areas. This aspect is discussed further in the section on non-mercurial dressings.

TREATMENT WITH BACTERICIDES

In the Sudan, evaluation of the toxicity of bactericides to *X. malvacearum* growing on culture media yielded results paralleling those obtained from field trials, in which naturally infected seed was treated with the bactericides and then sown out under conditions conducive to the disease, with subsequent counting of infected and healthy seedlings [24]. The numerous bactericides investigated showed a wide range of toxicity, but only mercury compounds gave adequate protection under Gezira conditions. Of the non-mercurials cuprous oxide showed most promise.

For many years Gezira sowing seed has been treated by mixing it very thoroughly with a finely divided bactericidal powder known as Abavit B, using a ratio of 1 : 150 by weight of powder to seed—about the maximum amount the seed will retain. Abavit B contains about 5·7% mercury as mercuric chloride (3 parts by weight) and mercuric iodide (1 part) and, at 1 : 150, gives about 0·038% mercury/seed. Although usually satisfactory for lightly infected seed, this treatment left 1–2% infected seedlings in some trials using heavily infected seed, and, as already pointed out, this degree of protection is inadequate under Gezira conditions.

Greater effectiveness was obtained by increasing the rate of dressing, but in practice much of the powder would be dislodged and wasted. Moreover, a dry dressing probably does not cause extensive destruction of blight bacteria, which may be protected by dried slime, until the treated seed is sown and thereby moistened. With Gezira sowing seed the maximum useful dosage is probably 1 : 150, and even at this rate experimental shaking of treated seed in sacks led to significantly poorer blight control, owing to loss of bactericide. Improved disinfection was also obtained by increasing the percentage of bactericide in the seed dressing, and a fortified Abavit powder of 8·5% mercury content applied at 1 : 150 (0·057% mercury/seed) was adopted as standard treatment for Gezira sowing seed. This has undoubtedly reduced the level of seed-borne infection in the Gezira, and in extensive trials with heavily infected seed gave an average per acre of some 170 infected seedlings as compared with 700 for Abavit B. There was no evidence of phytotoxicity even at 30% mercury content, but at the 50% level stunting and brown staining of roots became apparent. Admixture of certain dyes, e.g. brilliant green and methylene blue, with Abavit B powder to give 0·05–0·1% dye to seed resulted in poorer blight control, and caution should therefore be exercised in using them to colour cotton seed dressings and treated seed [24].

Per unit of mercury applied, several recently formulated organo-mercurial compounds, notably methoxyethylmercuriacetate (MEMA), were found to be somewhat more effective than mercuric chloride-iodide in the destruction of seed-borne infection. A further advantage of these compounds lies in their greater volatility, and a significantly reduced number of infected seedlings resulted from enclosing infected seed over, but not touching, an organo-mercurial seed dressing [24]. It seems advisable to treat seed early in order to prolong this fumigation effect, especially so in tropical areas where high temperatures would tend to accentuate it—provided, of course, that this practice does not unduly dissipate the potency of the dressing before the treated seed is sown.

METHODS OF APPLICATION

These have been extensively studied in the Sudan [24, 25, 27]. Powder treatment (dusting) has the important virtue of simplicity, but is unlikely to achieve such intimate and complete contact with the seed coat, fuzz and any lint present as would an adequate volume of bactericidal solution or suspension. Other advantages of wet treatments are: (1) disinfection occurs at the time of treatment; (2) after drying, the protective film of bactericide is firmly adherent to the seed and thus less liable to subsequent dislodgment than a powder; (3) flying dust is eliminated. On the other hand, wet treatments involve the use of relatively concentrated bactericidal solutions or suspensions which may be very poisonous and corrosive, as in the case of mercurials; seed subjected to some wet treatments may also have to be dried.

Steeping infected seed in 0·2% aqueous solution of mercuric chloride-iodide (4 : 1 by weight) for two hours, followed by quick sun drying, was more effective than treatment with Abavit B powder and about as good as that with strong Abavit. For small experimental quantities of well-ginned seed about 150 c.c. of solution per pound of seed often gave adequate wetting, but with larger quantities of other seed up to about 300 c.c./lb. was necessary, i.e. about 0·043–0·086% mercury/seed as compared with 0·038% for Abavit B and 0·057% for strong Abavit. Steeping large quantities of seed is a cumbersome and lengthy process necessitating specially designed and expensive machinery, both for steeping and subsequent drying. Other practical difficulties include metal corrosion, safety precautions, and the probable selective absorption of mercurials by cotton seed during steeping. Selective absorption would cause progressive weakening of the steeping solution, and the regular sampling and analysis required would increase the expense and complexity of the treatment. The water-soluble MEMA was more convenient to use and, per unit of mercury, more effective than mercuric chloride-iodide.

In slurry methods a small volume of relatively concentrated bactericidal suspension or solution is applied to the seed with vigorous rapid mixing. The bactericidal liquid probably has an immediate killing effect and quickly dries to form a thin, strongly adherent film over the seed. It is a rapid method without need for any special drying process, thus possessing many of the virtues but few of the drawbacks of steeping.

Experiments with mercuric chloride-iodide and organo-mercurial slurries applied to cotton seed in the Gezira gave promising results, provided certain conditions were fulfilled. Very rapid and thorough mixing of slurry liquid and seed is essential, so that a power-driven mixer has to be used. A somewhat high application rate of about 22·5 c.c. of slurry per pound of seed (roughly 5%) was necessary to ensure adequate wetting of many seed lots, but clean machine-delinted seed required

EFFECT OF SEED TREATMENT AGAINST BACTERIAL BLIGHT IN THE GEZIRA

Variety	Seed treatment	Resowing (%)	% infected holes, weeks after sowing						Blight severity	Yield (k.p.f.)
			5	7	9	11	13	15		
Sakel	S. Abavit ..	9·3	19	35	68	77	79	86	3·3	3·47
Sakel	MEMA s.w. ..	3·9	2	11	41	53	63	65	2·8	4·19
X1730A	S. Abavit ..	6·1	18	40	59	81	83	85	3·0	3·86
X1730A	MEMA s.w. ..	4·4	2	10	37	47	58	61	2·4	4·58

s.w. = short-wet treatment.
k.p.f. = kantars (315 lb.) of seed cotton per feddan (approx. an acre).
Blight severity was estimated on a 0–5 scale 15 weeks after sowing.

less, and smooth acid-delinted seed considerably less (e.g. 2½%). Here again MEMA was more effective than mercuric chloride-iodide and more convenient to use. Some 50 c.c./lb. (11%) was needed to wet a few seed lots, particularly those containing small quantities of intermixed lint. Since seed treated in this way dried rapidly under Gezira conditions and suffered no detectable injury, a standard application rate of 50 c.c./lb was adopted to ensure adequate wetting of all seed lots; the MEMA solution used contains about 0·39% mercury, giving 0·043% mercury/seed. Despite its smaller mercury/seed load as compared with strong Abavit (0·057% mercury/seed) this short-wet MEMA treatment was in all trials significantly the more effective, reducing infected seedlings to about 60/acre as compared with 150/acre with strong Abavit. Results of a trial using two varieties of Egyptian-type cotton are summarized in the table on page 171, the seed sown being samples taken from that sown commercially in the Gezira.

MEMA treatment reduced percentage resowing and bacterial blight infection, thereby increasing yields by 18–20%. In these trials initial differences in infection usually become obscured by subsequent spread of the disease.

MEMA short-wet treatment was as effective as a 2-hour MEMA steep, except in one trial in which exceptionally heavily infected seed was treated and sown out under conditions very favourable to the disease; in the same trial, however, double-strength short-wet treatment (0·77% mercury solution, giving 0·086% mercury/seed) was as effective as steeping at equivalent mercury application rate. It is highly unlikely that seed so heavily infected would ever be sown in the Gezira, but, if such were inevitable, double-strength treatment could be used.

Other experiments indicated that better disinfection of cotton seed is obtained from a smaller volume of more concentrated MEMA steep than from a larger volume of diluter steep, and that this concentration should not be less than about 0·1% mercury for 2-hour steeps but correspondingly more if the steeping period is reduced. This points the way to short-wet treatment using a small volume of relatively concentrated MEMA solution, provided that adequate wetting of the treated seed is obtained. Bearing in mind the many practical difficulties and inevitable slowness of steeping, it was recommended that short-wet treatment using 50 c.c. of MEMA solution of 0·39% mercury content per pound of seed, i.e. 0·043% mercury/seed, should be standard treatment in the Gezira.

APPLICATION OF SHORT-WET TREATMENT

In preliminary trials carried out in 1955 a power-driven revolving drum mixer was satisfactorily used for short-wet treatment of bulk cotton seed in the Gezira, MEMA solution being sprayed over the seed while it was in continuous motion inside the rotating drum. With a drum of 35 cu. ft. mixing capacity some 800 lb. of seed was treated in one operation lasting about 30 minutes, 10 of which were actual mixing time. With improved technique and experience this could probably be reduced to 15–20 minutes, or about 400 tons of seed treated per month of 12-hour working days, and output could be increased by using mixers of larger capacity.

Short-wet treatment had no phytotoxic effects on seed of low moisture content during the hot dry intercrop months in the Gezira; treated seed, although uniformly dampened, dried considerably during its passage along the sloping chute to the sacks and was bagged almost immediately without suffering detectable detriment. This happy state of affairs would probably not hold where atmosphere humidity is high, as in Uganda, where the seed contains more moisture and has to be treated during the main rains [31]. Under such conditions the addition of about 11% water, as in short-wet treatment, would probably damage the seed unless it were artificially dried after treatment, thus increasing expense, complexity and time involved. Smaller volumes of a stronger solution might be used provided that adequate coverage can be obtained or if a somewhat lower degree of control be acceptable. In the Gezira about 5% of liquid to seed seemed to be adequate for clean well-ginned seed of Egyptian-type cotton free from lint, but 2·8% (12·5 c.c./lb.) tended to give poorer control. Further investigation of these aspects in relation to seed of American-type cottons is needed.

NON-MERCURIAL SEED DRESSINGS

The poisonous nature of mercury seed dressings restricts their use in some areas. They can safely be applied under careful supervision at central seed treating stations, but misuse of treated seed, such as feeding it to stock, is difficult to control. The extent to which this occurs is uncertain, and the hazard may prove to be negligible. The fact that mercury compounds are by far the most effective yet found for destruction of seed-borne

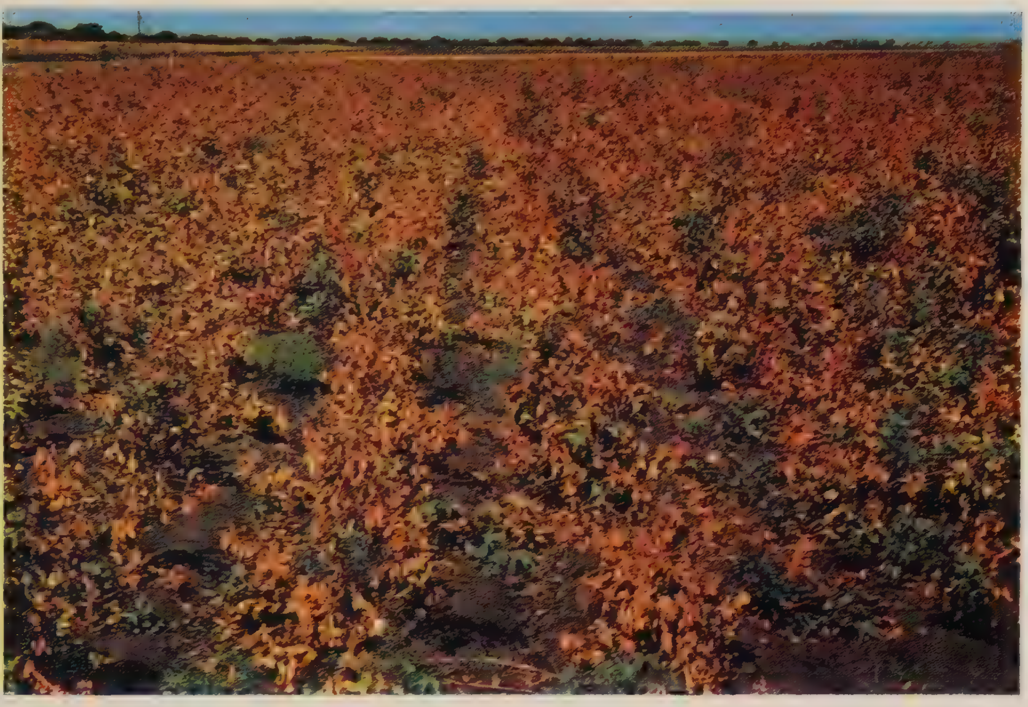


FIG. 1. Effect of an extremely bad attack of bacterial blight on the susceptible cotton variety X1730 in the Sudan Gezira, 1955.

bacterial blight makes their use highly advisable wherever possible; at present they are safely applied in the Sudan, Northern Nigeria, the United States and elsewhere, and doubtless will come into increasing use wherever cultivation of rain-grown cotton is being developed and extended.

Cuprous oxide, although the most effective non-mercurial compound yet found, is appreciably inferior to mercurials for control of seed-borne blight. In the Gezira, treatment of Egyptian-type cotton seed at 1 : 150 with a powder containing 50% copper as cuprous oxide reduced infection from about 35% to about 3%—an inadequate degree of control in the area. But with less susceptible cotton varieties grown in areas less favourable to the disease cuprous oxide usually gives worth-while control. Powder treatment of cotton seed with Perecot, a cuprous oxide formulation, is extensively practised in Uganda (21,000 tons of sowing seed per year), Tanganyika (6500 tons), Nyasaland and Kenya, and, although precise estimates are impossible, has undoubtedly resulted in crop increases far exceeding its cost of 1–2 shillings per acre [32].

In recent surveys throughout Uganda the number of plants with main stem blight lesions eight weeks after planting (taken as a measure of seed-borne infection) averaged about 57% for untreated seed and 9% for cuprous oxide treated seed in 1954, and 2–15% (average 6·4%) in 1955, when all sowing seed was so treated [31]. Nevertheless this reduced infection may, under certain climatic conditions, spread blight to the leaves and bolls later in the season, causing appreciable crop loss. In trials in Uganda and the Belgian Congo cuprous oxide seed treatment commonly reduced the numbers of young plants with main stem lesions to below 6%, but subsequent boll infection ranged from 19% to 64% [31], whereas in experiments in Uganda mercury seed dressings often gave effective control of the disease in all its phases. It seems that cuprous oxide, although considerably reducing seed-borne infection, may not provide adequate safeguard against the development of quite severe secondary infection if conditions favour the disease. In many areas, however, these circumstances do not usually arise, and yield increases of 150–200 lb. of seed cotton per acre (worth £3–£5) have resulted from cuprous oxide seed treatment in trials in Tanganyika. In the central Sudan, treatment of seed of rain-grown American-type cotton with Perecot had no effect on the yield of cotton planted on "new" land, but gave a 15% yield increase where the crop had been grown for three successive years [19]. Seed treatment with 20% copper trichlorophenate

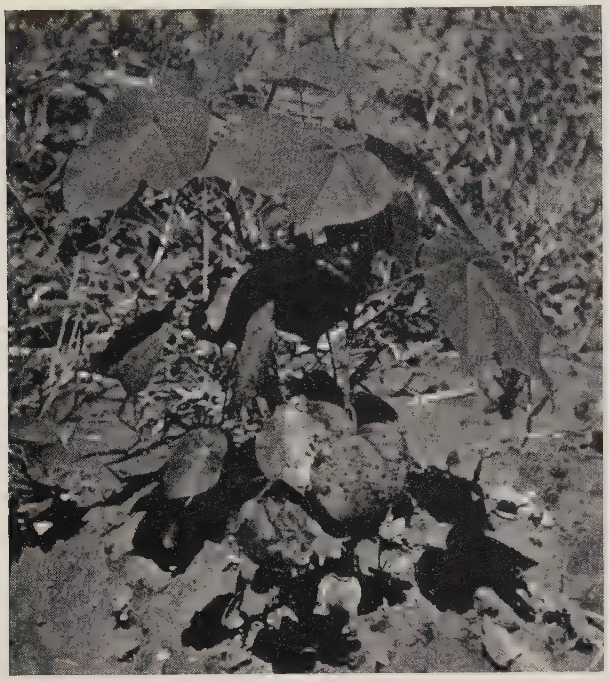


FIG. 2. Young cotton plant showing angular leaf spot and stunting caused by *Xanthomonas malvacearum*.

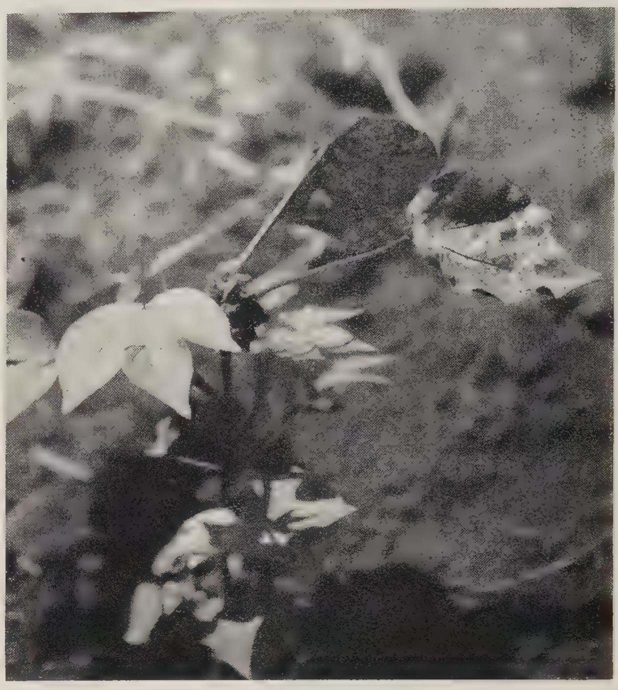


FIG. 3. Close-up of cotton leaf showing typical angular leaf spot caused by *Xanthomonas malvacearum*.

applied at about 1:150 is said to be effective in the Soviet Union [20].

Available information suggests that, although cuprous oxide seed treatment reduces seed-borne blight and so produces worth-while overall yield increases, greater benefits could be obtained by mercury treatment; this possibility should be carefully considered wherever the disease occurs.

In the Gezira, blight infection carried by cotton twigs and bolls is destroyed by immersing them in irrigation water for a few days, probably because a bacteriophage is present in, or develops in, the water. Similar steeping of seed reduced its infection but also its germinating power, a fact that largely prohibits the practice. It might, however, be possible to use 'phage preparations for this purpose.

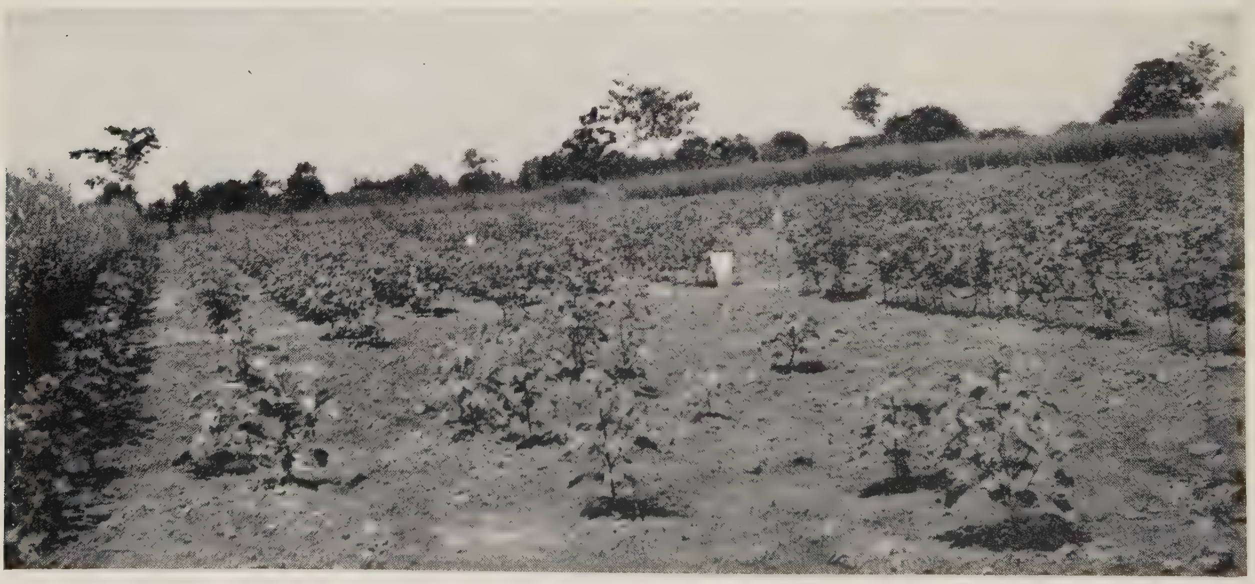


FIG. 4. Cotton seed treatment trial at Serere Experimental Station, Uganda, showing (*foreground*) control plot badly thinned by bacterial blight, and (*background*) plots sown with dressed seed.

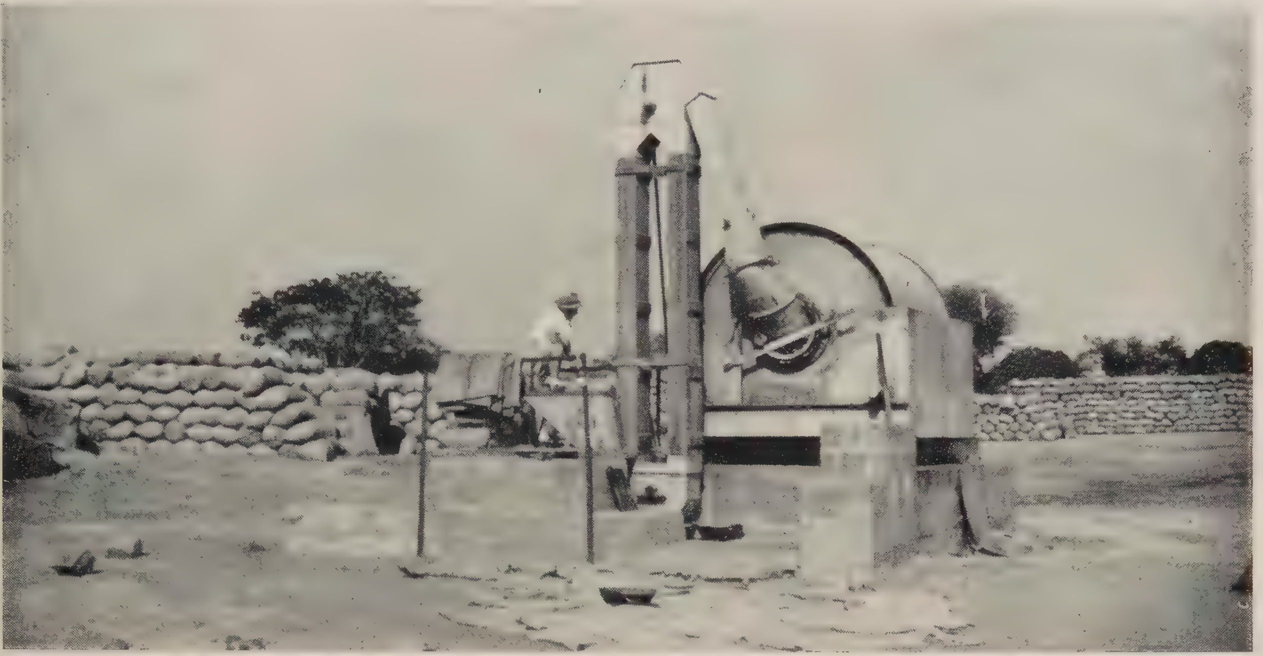


FIG. 5. A seed treater in use in Northern Nigeria for seed dressing of cotton.

SEED-BORNE DISEASES OTHER THAN BACTERIAL BLIGHT

Methods and problems of cotton seed treatment have been described above with special reference to bacterial blight, the most important seed-borne disease of cotton. Other diseases include the two fungal wilts caused by *Fusarium oxysporum* f. *vasinfectum* (*F. vasinfectum*) and *Verticillium albo-atrum*, Ascochyta blight and anthracnose [13]. Seed treatment is of little use for control of the wilt diseases, since the fungi concerned are mainly soil-borne.

Ascochyta blight, caused by the fungus *Ascochyta gossypii*, results in leaf spotting and blighting, stem canker, and boll rot. It occurs in North and South America, Africa, India, the Soviet Union and elsewhere, and is reported to be favoured by cool moist weather [21]. In the United States, where the disease has been studied, young cotton plants up to eight weeks old are particularly susceptible, and the most serious aspects are the loss of stand and early stunting resulting from seedling infection. The latter phase can be controlled by crop rotation combined with seed treatment, but this does not provide protection beyond the early seedling stage, and some internal seed infection may occur.

Anthracnose, caused by the fungus *Glomerella gossypii* (conidia *Colletotrichum gossypii*), incites seedling blight and boll rot in the more humid cotton-growing areas of the United States. It occurs in most countries where cotton is cultivated as a rain-grown crop, being favoured by wet conditions. It can cause serious loss of stand which is reported to be controllable by seed treatment, preferably by volatile organo-mercurials or zinc pentachlorophenate; these are applied as dusts at 1 : 500 for machine-delinted seed or 1 : 800 for acid-delinted seed, or as slurries. In Bombay State, India, anthracnose attributed to *Colletotrichum indicum* causes serious seedling blight and boll rot, and the former phase was effectively controlled by 1% organo-mercurial seed dressings applied at 1 : 120 by weight to the sowing seed, at a cost of about one rupee for four acres [4].

Ascochyta blight and anthracnose probably occur in many areas where cotton is grown under rain, but they have been investigated mainly in the United States, where much of the sowing seed is acid-delinted and thereafter treated with organo-mercurial powders. Acid-delinting destroys much of any seed-borne infection present, produces smooth seeds suitable for machine planting, and promotes rapid germination. Slurry treatment using such organo-mercurials as Ceresan M (7% ethyl mercury *p*-toluene sulfonanilide), and short-wet methods using Panogen (2·2% methyl mercury dicyandiamide), Mercuran (3·5% mercury as MEMA) and other soluble organo-mercurials are also applied to cotton seed in the United States.

IMPROVING EMERGENCE AND STAND

In addition to destroying seed-borne pathogens, seed treatment can give varying degrees of protection against soil fungi that rot planted seeds and damage seedlings before or shortly after their emergence from the soil, i.e. pre-emergence or post-emergence blights or "damping off." Such diseases are likely to occur when environmental conditions retard germination and early growth, as in cool or waterlogged soil, or when damaged seed is sown. They are a major factor reducing cotton yields in the United States, and in 1957 were estimated to have caused 2·4% crop loss of a total of 12% due to all diseases—a loss greater than that due to any other single disease [22]. The fungi involved are largely such soil inhabitors as *Pythium*, *Rhizopus*, *Fusarium* and *Corticium* (*Rhizoctonia*), the last-named being also seed-borne. Organo-mercurial and other seed dressings often provide fairly effective protection but may prove inadequate when environmental conditions greatly favour seedling diseases [6], and control by application of fungicides to the soil is being investigated [10].

In general, seed treatment encourages good germination and vigorous early growth, and the small cost of the operation is usually more than paid for by the increased yields obtained. Prolonged trials in Oklahoma indicated that seed treatment consistently improved cotton stands, the organo-mercurial Ceresan M giving an average increase of nearly 11% [5]. The application of more potent and more persistent fungicides, as such are discovered, will lead to increasingly effective control by seed treatment of the soil fungi that damage cotton seedlings. Where cotton is sown in soil conducive to rapid germination and vigorous early growth the beneficial effects of seed treatment may be difficult to demonstrate; this aspect needs investigation in Africa and Asia, present evidence indicating that seed treatment is likely to be most effective in places where environmental conditions result in slow germination, or where the crop is sown in the same field over several successive seasons.

SEED TREATMENT AGAINST INSECT PESTS

Pink bollworm (*Platyedra gossypiella*), a major pest of cotton in Egypt and the Sudan, persists between crops partly as resting larvae inside seeds. These larvae can be destroyed either by exposing infested seed in a thin layer to bright sunshine, so that a temperature of 60° C. is reached and maintained in the seed for several hours, or by carefully controlled heat treatment. In the Sudan it is probable that steeping seed in mercuric chloride-iodide solution for two hours for destruction of bacterial blight also kills any bollworm larvae present. Whether organo-mercurial steeps, slurries and powders, either alone or with added insecticide, would have a similar effect has yet to be ascertained.

Insecticidal seed treatment may also protect seed and young seedlings from attack by soil-borne or air-borne insect pests; application of this valuable method of pest control to cotton is still largely in the experimental stage, and some of the preliminary results obtained are outlined below.

There are indications, which need further investigation, that incorporation of gamma-BHC in the seed dressing may afford some protection against flea-beetles (*Podagrica* spp.) and possibly other insects that attack cotyledons and young leaves of cotton seedlings in the Gezira.

In the same area mercury-dieldrin seed treatment protected cotton seedlings against termite attack of the roots, in one experiment reducing mortality from 9–12% (untreated seed) to 0·1–0·3% and resulting in more vigorous growth, higher plant populations and yield increases of 12–17%. Gamma-BHC appeared to be slightly less effective, while MEMA alone produced these beneficial effects to a slight but appreciable extent and presumably has some insecticidal or insect-repelling properties. The insecticides were applied at 0·12–0·24% by weight to seed (about 15–30 g./acre). Combined Abavit-insecticide or MEMA-insecticide seed dressings sometimes caused slight phytotoxicity, particularly at the 0·24% gamma-BHC seed rate. Soil insects other than termites may have been involved; thus chafer grubs (*Schizonycha* sp.) cause root damage to several crops in the Gezira and can often be controlled by fungicide-insecticide seed treatment [26, 28]. Further research may show this method of crop protection to be a simple and inexpensive means of increasing Gezira cotton yields.

Systemic insecticides are likely to find extensive application on cotton, a fibre crop not used for food. In the United States cotton belt Thimet, Di-Syston and schradan (all organo-phosphorus systemic insecticides) applied as seed dressings at rates equivalent to ½–1 lb. a.i./acre effectively controlled aphids (*Aphis gossypii*), thrips (*Frankliniella* sp.) and spider mites for 4–6 weeks after sowing, and showed promise against flea-beetles, leaf-hoppers (*Empoasca solana*), flea-hoppers (*Psallus seriatus*), white-flies (*Trialeurodes abutilonea*), leaf miners (*Liriomyza* sp.), darkling ground beetles (*Blapstinus* sp.), black cutworm (*Agrotis ypsilon*) and others [1, 8, 9, 15–17]. In many cases early growth was improved, but phytotoxicity was evident in some trials [8, 15]. In trials in Brazil Thimet (45% a.i.) applied at 4% by weight to slightly wet seed, and schradan at the same rate, both applied in activated carbon, gave good control of *Aphis gossypii* for some ten weeks and substantially increased yields. Di-Syston (50% a.i.) at the same rate satisfactorily controlled aphids for 10–14 weeks, and also spider mite (*Tetranychus telarius*), but not the broad mite (*Hemitarsonemus latus*) [2, 23].

Many of the systemic insecticides are organophosphorus compounds very toxic to man and other mammals, thus necessitating extremely careful use. The relatively heavy application rate often needed may involve special methods for "sticking" the insecticide to the seed, e.g. Hopkins *et al.* [9] used 8 lb. of carbon powder containing 44% of Thimet and 2% of methyl cellulose per 100 lb. of cotton seed. Compatibility with the bactericidal or fungicidal components of the seed dressing must be considered. For example, Thimet 44D is reported to be incompatible with the organo-mercurial Ceresan 200 but not with Captan; it seems that either the insecticide or its highly absorptive carrier (activated charcoal) inactivates the Ceresan [7]. There is some evidence that seed may show a tendency to decay if treated with insecticide alone [12], and that combined fungicide-insecticide treatment is more advantageous. Account must also be taken of the relative merits of seed treatment, soil treatment, and foliage spraying as methods of controlling individual cotton pests. Much research is clearly needed in this field and is likely to yield results of great practical value. Insect control by seed treatment has recently been reviewed by Lange [11], and the use of systemic insecticides in this respect by Reynolds *et al.* [17].

CONCLUSIONS

Many of the diseases and pests which attack cotton cannot be controlled with seed dressings now available. Nevertheless, more extensive application of known and proven methods of seed treatment would save much crop at present lost, and the scope of this simple and inexpensive method of crop protection will increase as more efficient and more persistent seed treatment chemicals are discovered. The use of systemic fungicides, insecticides and bactericides in seed treatment constitutes a field of research likely to prove of great benefit to cotton growers. We may perhaps look forward to the day when treatment of cotton seed before sowing will protect the crop against attack by pathogenic fungi, bacteria and insect pests (including vectors of virus diseases) during the vital first few weeks of its existence, and the use of more persistent chemicals might enable this period of protection to be extended.

REFERENCES

[1] ADKISSON, P. L. (1958). *J. econ. Ent.*, **51**, 697–700.

[2] ALMEIDA, P. R., *et al.* (1957). Abstr. in *Emp. Cott. Gr. Rev.*, **35**, 220.

[3] ANON. (1958). *Emp. Cott. Gr. Rev.*, **35**, 73.

[4] BHIDE, V. P., *et al.* (1957). Abstr. in *Emp. Cott. Gr. Rev.*, **35**, 142–3.

[5] BRINKERHOFF, L. A. (1951). Abstr. in *Rev. appl. Mycol.*, **32**, 677.

[6] BRINKERHOFF, L. A., *et al.* (1954). *Plant Dis. Reptr*, **38**, 467–75.

[7] ERWIN, D. C. and REYNOLDS, H. T. (1958). *Plant Dis. Reptr*, **42**, 174–6.

[8] HANNA, R. L. (1958). *J. econ. Ent.*, **51**, 160–3.

[9] HOPKINS, A. R., *et al.* (1958). *J. econ. Ent.*, **51**, 100–2.

[10] KENNEDY, B. W. and BRINKERHOFF, L. A. (1959). *Plant Dis. Reptr*, **43**, 90–7.

[11] LANGE, W. H. (1959). *Annu. Rev. Ent.*, **4**, 363–88.

[12] LANGE, W. H., *et al.* (1949). *J. econ. Ent.*, **42**, 942–55.

[13] NOBLE, M., *et al.* (1958). *An annotated list of seed-borne diseases.* Commonwealth Mycological Institute.

[14] PADWICK, G. W. (1956). *Losses caused by plant diseases in the Colonies.* Commonwealth Mycological Institute Phytopathological Paper No. 1.

[15] PARENCIA, C. R., *et al.* (1957). *J. econ. Ent.*, **50**, 31–6, 614–7.

[16] PARENCIA, C. R., *et al.* (1958). *J. econ. Ent.*, **51**, 872–5.

[17] REYNOLDS, H. T., *et al.* (1957). *J. econ. Ent.*, **50**, 527–39.

[18] ROLFE, F. M. (1935). *Phytopathology*, **25**, 971.

[19] ROSE, M. F. and LOW, A. (1955). *Emp. Cott. Gr. Rev.*, **33**, 70.

[20] SHVER, E. (1955). Abstr. in *Emp. Cott. Gr. Rev.*, **32**, 304.

[21] SMITH, A. L. (1953). *Plant Diseases. Yearb. Agric., U.S. Dep. Agric.*, 1953, pp. 303–11.

[22] SMITH, H. E., *et al.* (1958). *Plant Dis. Reptr*, **42**, 169–71.

[23] SOUZA, M. F., *et al.* (1957). Abstr. in *Emp. Cott. Gr. Rev.*, **35**, 289.

[24] TARR, S. A. J. (1953). *Emp. Cott. Gr. Rev.*, **30**, 19–33.

[25] TARR, S. A. J. (1953). *Emp. Cott. Gr. Rev.*, **30**, 117–32.

[26] TARR, S. A. J. (1954). *Ann. appl. Biol.*, **41**, 578–85.

[27] TARR, S. A. J. (1956). *Emp. Cott. Gr. Rev.*, **33**, 98–104.

[28] TARR, S. A. J. (1958). *Ann. appl. Biol.*, **46**, 630–8.

[29] TENNYSON, G. (1936). *Phytopathology*, **26**, 1083–4.

[30] WEINDLING, R. (1944). *Phytopathology*, **34**, 235–9.

[31] WICKENS, G. M. (1957). *Emp. Cott. Gr. Rev.*, **34**, 170–6.

[32] WICKENS, G. M. (1958). *Emp. Cott. Gr. Rev.*, **35**, 9–12.

THE USE OF VIRUSES IN THE BIOLOGICAL CONTROL OF INSECT PESTS

Kenneth M. Smith

(*Agricultural Research Council, Virus Research Unit, Huntingdon Road, Cambridge*)

A promising start has been made in controlling insect pests by infecting them with virus diseases. Within the past decade specific viruses have been found, propagated, and applied in the field with good results, especially against larvae that feed gregariously on leaves. Perpetuation of disease by virus transmission through the insect egg and other features of virus behaviour ensure that the possibilities of the new method will be fully explored.

The idea of trying to control insect and other pests of agricultural crops by "setting a thief to catch a thief" is not a new one. Biological control, as it is usually called, has been used widely, not always with success. The earliest efforts in this direction employed mainly predacious or parasitic insects, which were produced in large numbers under laboratory conditions and then introduced into the area where the pest in question was active.

In the early days of biological control there were three large-scale attempts to eradicate certain insect pests by the introduction of predacious or parasitic insects. In 1888 the vedalia beetle, *Rodolia cardinalis* (Muls.), was introduced from Australia into California to control the cottony-cushion scale, *Icerya purchasi* Mask., on citrus. In 1874 a ladybird beetle, *Coccinella undecimpunctata* L., was sent from England to New Zealand to try to keep down aphids. Then in 1883 the hymenopterous parasite, *Apanteles glomeratus* L., was also sent from England to the U.S.A. in an attempt to control the caterpillars of the white butterfly. Of these three experimental introductions the importation of the vedalia beetle was the most successful, and the cottony-cushion scale is no longer a serious menace to the citrus industry.

Biological control, however, is not confined to the encouragement of predatory insects, and more attention is now being paid to the possibility of starting epidemics of disease among agricultural pests. Both bacterial and fungal disease agents have been tried, and some success has been obtained with a bacterial disease of the Japanese beetle, *Popillia japonica* Newm., by producing the spores of *Bacillus popilliae* Dutky, the causal agent of the milky disease, in large quantities and disseminating them in the soil against the larvae in the eastern United States.

The idea of using viruses in biological control is also not new, the classical example being the introduction of the myxoma virus into Australia against the rabbit pest and, more recently, into France and Great Britain. What is new is the use of viruses to control insect pests, and this is not surprising since it is only during the last decade that insect viruses have been seriously studied. For some reason these agents have been neglected by virologists, which is a pity, because they are of great interest and quite suitable for fundamental studies on the nature of viruses.

In a former issue of this journal Bawden [1] described the nature of plant viruses and showed that all those isolated were nucleoproteins consisting of protein and ribonucleic acid (RNA). All the insect viruses so far isolated are also nucleoproteins, but the majority contain desoxyribonucleic acid (DNA), though a few are RNA viruses. Their size variations are greater than those of the plant viruses, for they range from about 400 mμ down to 12 mμ, whereas the majority of the near-spherical plant viruses measure 25–30 mμ (1 mμ or millimicron $= 10^{-6}$ mm.). In two of the largest groups of insect viruses, however, there is a characteristic phenomenon, the enclosure of the virus in a protein crystal, which differentiates them sharply from the plant viruses and from viruses infecting the higher animals. This characteristic is of practical importance when a virus is being selected for control purposes.

The great majority of insect viruses attack the immature or larval stages of the host.

TYPES OF INSECT VIRUSES

So far as is known at present, insect viruses fall into three main groups. In the first two, the polyhedral diseases or polyhedroses and the granular diseases or granuloses, the virus particles are enclosed in protein crystals to which these names refer. In the third group there are no enclosing crystals and the virus particles are free in the tissues, as with the virus diseases of plants.

The polyhedral type of disease has been known for many years and was probably first observed in the silkworm, in which it causes a yellowing of the skin, giving rise to the name of "silkworm jaundice." There are two types of polyhedrosis, the nuclear and the cytoplasmic, according to the site of multiplication of the virus, and in both of them certain tissues of the affected larvae contain huge numbers of many-sided (polyhedral) crystals.

In nuclear polyhedroses the tissues involved are usually the skin, tracheae and the blood. For many years these crystals were the subject of controversy as to whether they were the cause or the effect of the disease, and some workers even considered they were a new type of organism. Now, however, it is known that they are not the causal agent but contain the virus within them; this is easily demonstrated by dissolving a polyhedral crystal in weak alkali and taking a picture on the electron microscope. Figure 1 illustrates this: a nuclear polyhedral crystal has been dissolved, leaving behind a thin membrane which enveloped the crystal together with the rod-shaped virus particles.

The cytoplasmic type of disease has only recently been discovered, and it differs from the foregoing in several important particulars. When the polyhedral crystals are treated with weak alkali they do not dissolve completely but leave behind a shell honeycombed with round holes, these being the sockets which contained the spherical virus particles, and no membrane encloses the crystal (Figure 3). The crystals occur mostly in the gut, and the disease produced differs considerably from nuclear polyhedroses. As will be explained later, the type of disease has a practical bearing from the point of view of biological control.

In the granular type of virus disease there are no polyhedral crystals, and their place is taken by thousands of very small "granules" which give the disease its name. These granules, which can just be resolved with the oil-immersion lens of the optical microscope, are really minute crystals containing, as a rule, a single rod-shaped virus particle. They can be treated with weak alkali and observed on the electron microscope, as with the other two types of virus (Figure 2). The skin and tracheae are the tissues usually attacked, and the disease caused resembles that of the nuclear polyhedrosis.

Only two viruses without intracellular inclusions have so far been isolated and characterized on the electron microscope: one is from the larva of a moth, the so-called army worm or processionary caterpillar, and the other from the larva of a common fly, the crane fly or daddy-long-legs, *Tipula paludosa.*

EFFECTS OF VIRUS DISEASES

The distribution of virus infections in the insect kingdom appears to be very uneven, but this may be merely a reflection of our lack of knowledge. The greatest number of viruses, mostly causing polyhedral diseases, undoubtedly occurs among the larvae of the Lepidoptera (butterflies and moths), as anyone who has tried to rear caterpillars will agree. There are several virus diseases of hymenopterous larvae (sawflies), and two have been recorded from the larvae of Diptera (two-winged flies). No authenticated case of a virus disease has been recorded in the Orthoptera (grasshoppers, locusts and cockroaches), Hemiptera (aphids and plant bugs), or Coleoptera (beetles), though no doubt viruses exist in these Orders and will be discovered sooner or later.

The manifestations of virus diseases in insects seem to depend very largely on the tissues affected. Thus, in the nuclear polyhedroses and in the granuloses the skin is attacked and rendered excessively fragile; it ruptures at a touch and liberates the liquefied body contents, including the polyhedra or granules, over the food plant (Figures 6 and 7). With the cytoplasmic polyhedroses, and where the virus is free in the tissues, the skin is not attacked. When these larvae die the body becomes flaccid and eventually dries up, unless, as frequently happens, secondary invasion by bacteria hastens the destruction of the body. In caterpillars that have died of a cytoplasmic polyhedrosis, white patches are often visible through the skin; these are masses of polyhedral crystals situated in the mid- or hind gut (Figure 4).

OBTAINING AND APPLYING THE VIRUSES

It should be understood, first of all, that a virus specific for the insect must be found. In other words, except under special circumstances, which are dealt with later, it is no use applying any insect virus and hoping it will attack the particular pest. How the virus is to be found is merely a question of looking for it. The procedure is simple enough and consists in the systematic examination of all dead or apparently diseased individuals of the insect to be controlled. The polyhedral diseases are easily identified, and the routine test consists in making a blood smear of the larva on a slide, fixing it with heat, and staining with Giemsa's solution.

Under the oil-immersion lens of the optical microscope the polyhedral crystals are readily detected. But where the disease is caused by a virus free in the tissues and there are no intracellular inclusions, identification is more difficult and an electron microscope must be used.

Having obtained the necessary virus the next step is to produce it in sufficient quantities for use in control. Since it is a fundamental property of viruses that they cannot multiply outside a living cell, it follows that the virus must be propagated in the insect itself. Large quantities of the larvae must therefore be raised and infected artificially with the virus. In the case of the polyhedroses and granuloses the bodies are collected and stored in water contained in large conical flasks; these are left standing at room temperature for some weeks to allow the bodies to disintegrate and the polyhedra or granules to sediment to the bottom of the flask. The debris is then decanted and the virus material collected by centrifugation. A stock of the infective material can be kept indefinitely.

Polyhedral and granular viruses are the most suitable for use in biological control, for they are easily identified by means of the optical microscope, and, more important, the occlusion of the virus itself inside a protein crystal not only protects the virus from environmental conditions but allows it to be sprayed in a viable and convenient form. In nature the polyhedral crystals assist the spread of the disease in a remarkable manner: they are extremely resistant to cold and other factors and may retain their infectivity for years. Some are carried by the wind, while others remain on the food plant to infect later broods of larvae.

Spread of insect viruses in the field is mainly by ingestion of virus-contaminated food plants and by inheritance from infected parents. There is little doubt that many of the insect viruses are passed through the egg to subsequent generations, and this, of course, is of great significance in the matter of control. It is thus possible to get a virus seeded into a population of insects and affect future generations in a way no insecticide can do. Contamination of the food plant is also important and is closely bound up with the virus and the type of disease induced by it.

The nuclear type of polyhedral disease and the granuloses attack the skin and reduce the body contents to a semi-liquid material containing millions of polyhedra or granules. The skin ruptures and the liquid contents run down the stem of the plant (Figure 7) or are splashed around by rain. Moreover, these liquefied cadavers can be attractive to the uninfected larvae, which feed upon them with disastrous results. Cytoplasmic polyhedral viruses do not have this liquefying effect upon the body, nor do they attack the skin, so the polyhedra are not so easily spread. This is partly compensated for, however, by the fact that large quantities of polyhedra are voided with the faeces and contaminate the food plant.

Application of the virus in the control of the insect pest follows the methods used for spraying insecticides. Preliminary trials may be required to get a rough idea of the number of polyhedra per ml. necessary for good control; usually the number is about a quarter to half a million, and the polyhedra can be conveniently estimated by the use of a device for counting blood cells.

The normal procedure is for the polyhedra to be suspended in water and applied with a low-volume sprayer at the rate of 10–15 gallons to the acre. Sometimes it is necessary to add a "sticker" of some kind to make the polyhedra adhere to the leaves, but as a rule they stick quite well and are not easily washed off by the rain.

Feeding habits are also important in determining if an insect will be amenable to this kind of control. The greatest success is likely to be attained with insects that feed openly and gregariously on the leaves of the plant; insects that live in the soil or feed hidden inside a stem or bud are much more difficult to reach with a virus suspension.

ATTEMPTS AT CONTROL

Some of the pioneer work in this form of control was done in the U.S.A. One notable attempt was made in California against a serious pest of lucerne, the caterpillar of the clouded yellow butterfly (*Colias philodice eurytheme* Boisd.). The caterpillars feed openly on lucerne and are easily reached with a virus suspension. A polyhedral virus was used and an initial supply was built up by infecting caterpillars in the insectary; this was then used to spray a field containing a high population of caterpillars. By collecting the infected larvae in the field with a sweeping net on the day before they are expected to die of the disease, large quantities of the virus may be obtained: in one of the field tests where approximately half a pint of the suspension was applied, 7 gallons of virus material were recovered in 4 hours' time on the sixth and seventh days after treatment [6]. Spraying was done both by aeroplane and by ground equipment. The

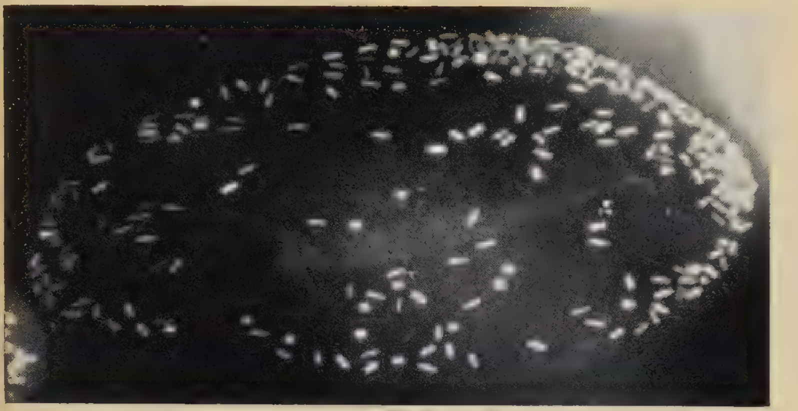


FIG. 1. Electron micrograph of a nuclear polyhedral crystal from a larva of *Lymantria monacha*, the nun moth. The crystal has been dissolved in weak alkali, leaving behind the rod-shaped virus particles in the enclosing membrane.

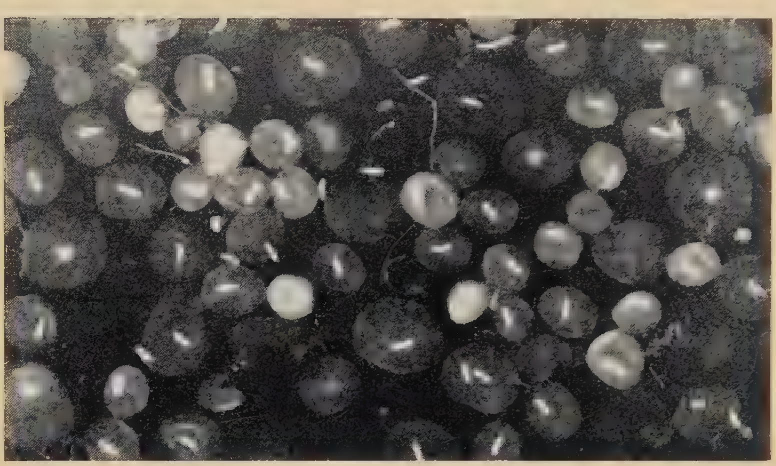


FIG. 2. Electron micrograph of the "granules" from a granulosis disease of the larvae of *Pieris brassicae*, the large white butterfly, treated similarly to the polyhedra in Figures 1 and 3. The rod-shaped virus particle is not visible but is contained inside the inner capsule.

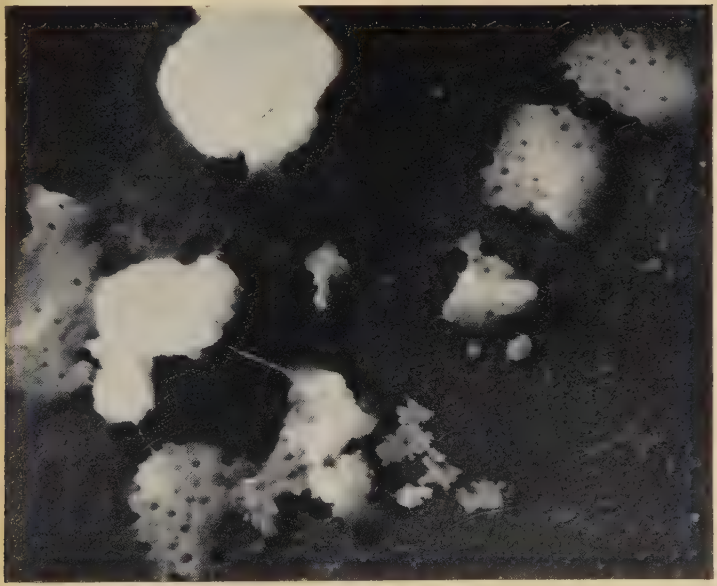


FIG. 3. Electron micrograph of a cytoplasmic polyhedral crystal from a larva of *Phlogophora meticulosa* treated similarly to that in Figure 1. Note the round holes in the residue of the crystal which contained the spherical virus particles and the absence of a membrane.

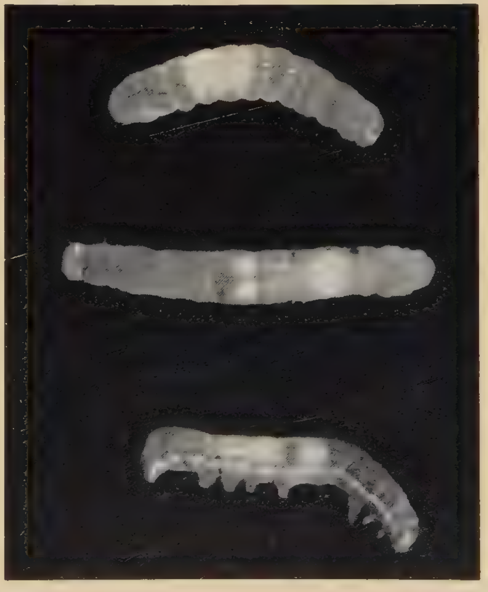


FIG. 4. Larvae of *Phlogophora meticulosa* killed by the virus from the polyhedra shown in Figure 3. Note the white patches where the polyhedra show through the skin.

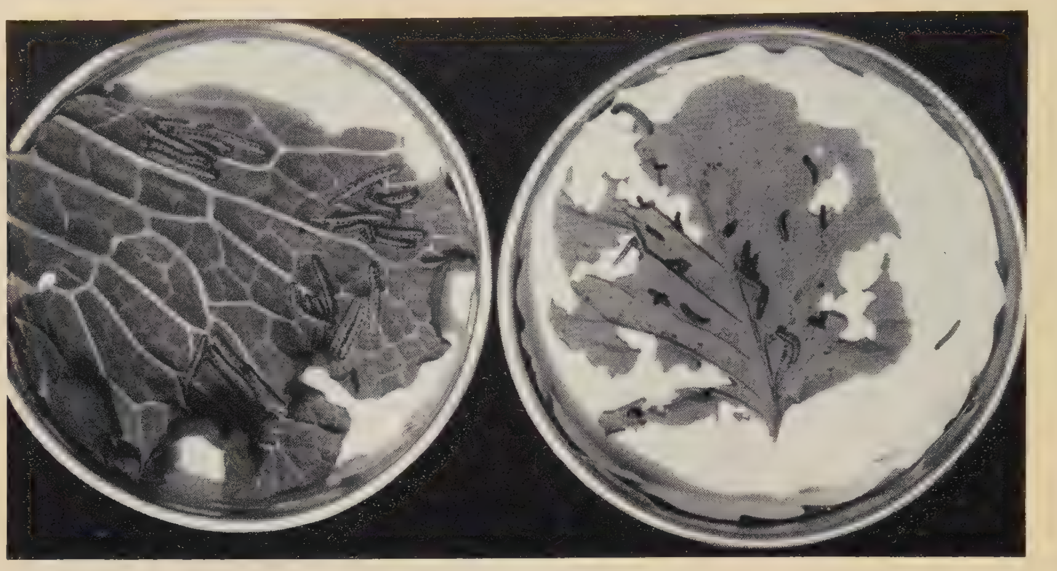


FIG. 5. The effect of feeding a granulosis virus to the caterpillars of the large white butterfly, *Pieris brassicae*: (right) 96 hours after feeding on a virus-contaminated leaf; (left) control caterpillars of the same age.

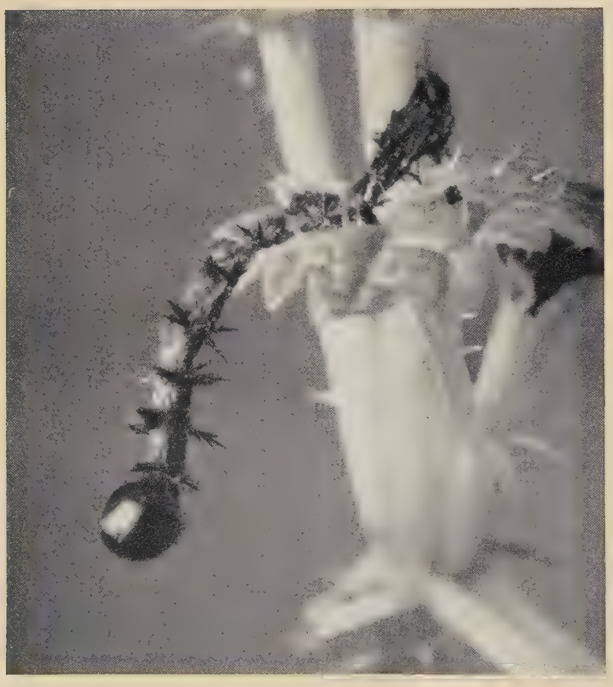


FIG. 6. Larva of a Vanessid butterfly affected with a polyhedral virus disease. Note the liquefied body contents collected at the head end.

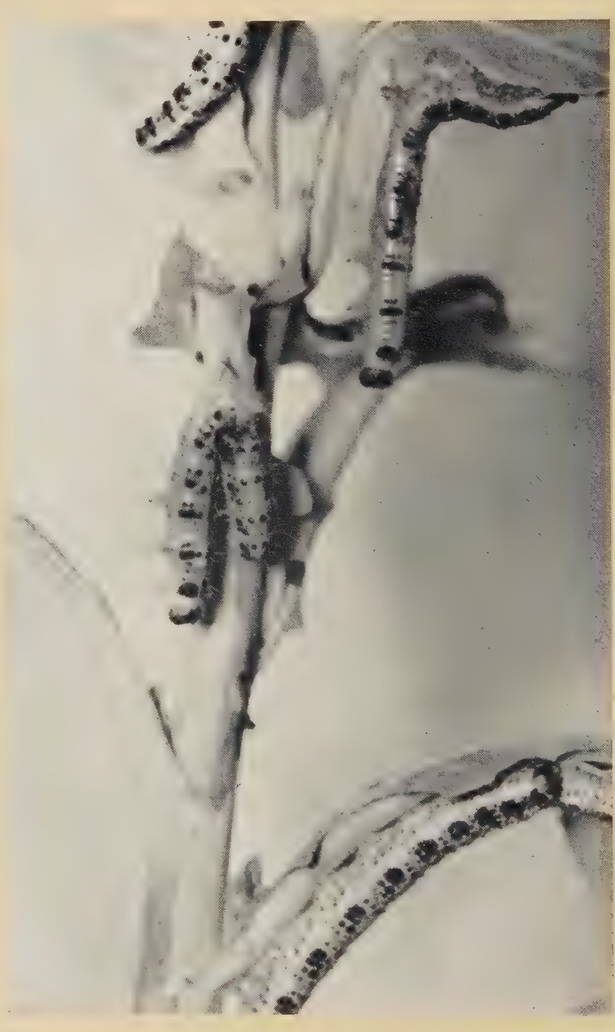


FIG. 7 (right). Larvae of the large white butterfly, *Pieris brassicae*, killed by the granulosis virus shown in Fig. 2. Note the characteristic position of the dead larvae and the drop of fluid full of granules at the bottom of the stem.

authors conclude that more extensive trials are necessary before it can be said that this method of controlling the lucerne caterpillar is an economic success. Timing of the application is extremely critical, because once damage begins to show in the field it is too late to use the virus as a practical means of control. In fields with very high populations it may be necessary to apply the virus before the caterpillars hatch from the eggs.

Another interesting experiment was carried out in Canada against the European pine sawfly, *Neodiprion sertifer* (Geoffr.) [2]. The larvae of this sawfly resemble caterpillars in some ways and feed gregariously on the foliage of the Scotch pine. The insect was first reported in Canada at Windsor, Ontario, in 1939 and by 1949 had spread throughout most of the south-western part of that province. No virus disease had been observed in the sawfly populations in Canada, but a polyhedral disease of the same insect was known in Sweden. The virus was imported into Canada and propagated until enough was available for testing on a large scale; it was then sprayed over the forest by means of an aeroplane. Mortality from the disease was found to depend on the amount and concentration of virus used, the method of dissemination, and the stage of larval development at the time of spraying. To produce the greatest mortality the virus should be applied at, or soon after, the time of hatching of the eggs, but serious defoliation could be prevented by treatment before the larvae reached the fourth instar.

Similar experiments on the large-scale use of a polyhedral virus to control defoliating larvae are being carried out in South Africa by Ossowski [4]. The insect concerned, *Kotochalia junodi* (Heyl.), is known as a "bagworm" because it lives inside a case or bag made of plant material or debris. It is indigenous to South Africa, where it lives on species of *Acacia*, from which it has invaded plantations of black wattle (*A. mollissima* Willd.) —a crop of considerable economic importance.

Aqueous suspensions of 10,000 polyhedra per cu. mm. caused a very high mortality which was not increased when greater concentrations were used. Such suspensions remain effective for a considerable time, so that they can be applied some months before the bagworms hatch. This may ensure a high mortality of the newly hatched larvae and thus save time in large-scale applications. There seems to be no danger that the polyhedral bodies will be washed off the trees by rain, for Ossowski relates that during one experiment a total of over 550 mm. of rain fell without apparently impairing the efficacy and distribution of the polyhedra.

Experiments on a smaller scale are being carried out in Great Britain. As a preliminary to this work, viruses were found which would attack about twenty species of injurious insects in Britain [5]. Many of these viruses are not suitable for practical use and some of the insects are not of sufficient economic importance to warrant the experimental effort, but work is being carried out on the control of the larvae of the following pests: the two white butterflies *Pieris brassicae* and *P. rapae*, the pine sawfly *Neodiprion sertifer*, and two species of clothes moth, *Tineola bisselliella* (Hummel) and *Tinaea pellionella* (L.).

A granulosis virus was used against the caterpillars of the white butterflies. This virus attacks the skin of the larvae and reduces the body contents to a liquid mass, so that the highly infectious "granules" are readily spread (Figure 7). The caterpillars are extremely vulnerable to attack by means of a virus suspension, for they feed openly and in large numbers on low-growing brassica crops which are easily reached with a spray. The granulosis virus used is highly infectious and virulent, so much so that five fully grown caterpillars in an advanced stage of the disease are sufficient to make one gallon of spray. The virus suspension is made up in water, and a "sticker" is added to make it adhere to the waxy brassica leaves. It must be applied as early in the attack as possible, but the effect is fairly rapid and infected larvae stop feeding some time before the disease becomes manifest (Figure 5). Unfortunately for the purposes of experiment, serious attacks of these caterpillars occur only at intervals, and the opportunity to try out the virus on a large scale has not yet been forthcoming.

Immediate practical results have been achieved against the larvae of the pine sawfly on a plantation in Norfolk, where a local but severe outbreak of the pest occurred. Half the plantation was sprayed with a suspension of polyhedra and the other half left unsprayed as a control. The virus has not been recorded in England, though it does occur in Scotland, and its introduction seems to have been very successful, for a mortality of about 80% was obtained. Moreover, when the plantation was visited again in the following year it was found that the virus had moved across to the unsprayed part of the plantation, and again a heavy mortality had resulted. How the virus got into the control plantation in such a high concentration is not quite clear; it seems unlikely that the wind could have carried over sufficient polyhedra. A possible explanation is that infection was transmitted through the eggs of sawflies arising from larvae that had picked up the virus in a late stage of their development. Such larvae may have failed to develop the disease yet have retained some virus throughout the metamorphosis. It is to be hoped that the virus will now become established in the local populations of sawfly larvae and that periodic outbreaks of the disease will be sufficient to keep the pest under control.

Control of the clothes moths is not of direct agricultural interest, and it need only be mentioned here that the methods used are much the same, the main difficulty in the way of the successful use of this virus being the small size of the larva and the low concentration of virus obtainable in consequence.

FUTURE POSSIBILITIES

It will be clear from this article that the use of viruses in the control of insect pests is only just beginning and that much more investigation into the possibilities is needed. Indeed, each attempt to apply the method is a separate piece of research in which all the variable environmental factors governing this type of biological control must be taken into consideration. It may be permissible, however, to speculate a little on some possible future developments. We have seen that in several large Orders of insects no viruses have ever been discovered, and the same applies to individual pests belonging to Orders in which viruses have been recorded. What are the possibilities of inducing virus diseases in insects that have never been known to be thus infected? This is a fascinating problem and one which has hardly been investigated. It can be approached from two aspects: attempts can be made, first, to take advantage of the phenomonon of latent virus infections which are widespread in the insect kingdom, and, second, to infect the pest with a virus from a different insect host.

It is an interesting fact that large populations of insects carry latent infections, usually of the cytoplasmic polyhedral type. These can sometimes be stimulated into activity by stress factors such as overcrowding and excess humidity. Frequently, too, a latent virus infection can be "triggered off" by inoculation with a foreign virus. A case in point is the caterpillar of the winter moth, *Operophtera brumata*, which has never been found with a natural virus infection. When apparently healthy caterpillars of this moth were fed with a *nuclear* polyhedral virus from the caterpillar of the painted lady butterfly, *Vanessa cardui*, a cytoplasmic polyhedral disease developed, and this, once stimulated into action, could be transmitted to other winter moth larvae and a supply of the virus built up. This is an instance of stimulating a latent virus in an insect belonging to an Order in which many viruses occur, but we can envisage the application of the method to other Orders of insects with no record of virus infection.

The second approach to this problem is to try to infect a given insect with a foreign virus, and not just stimulate a latent infection. The axiom has been laid down that all insect viruses are species-specific; but axioms are liable to hold up progress in scientific research, and this one is no exception. Although it is true that a virus may be highly specific when attempts are made to transmit it by feeding to other insect species, this may not hold if the virus is injected into the insect by means of a microneedle. Viruses have been transmitted by this method from one insect to another in which no virus disease had previously been described.

As research proceeds, viruses may be discovered in agricultural pests other than Insecta. For example, a recent note by Munger *et al.* [3] in California records an infectious disease of the citrus red mite, which belongs to the Arachnida. If this turns out to be a virus a new chapter in the control of a formidable group of pests will have been opened.

ACKNOWLEDGMENT

Thanks are due to Mr. Simon Frey for taking the photographs used to illustrate this article.

REFERENCES

[1] Bawden, F. C. (1957). *Outlook on Agriculture*, **1**, 244–51.
[2] Bird, F. T. (1953). *Canad. Ent.*, **85**, 437–46.
[3] Munger, F., Gilmore, J. E. and Davis, W. S. (1959). *Calif. Citrogr.*, **44**, (6), 190, 216.
[4] Ossowski, L. L. J. (1957). *Ann. appl. Biol.*, **45**, 81–9.
[5] Smith, Kenneth M. and Rivers, C. F. (1956). *Parasitology*, **46**, 235–42.
[6] Thompson, C. G. and Steinhaus, E. A. (1950). *Hilgardia*, **19**, 411–41.

CLOSTRIDIAL DISEASES OF SHEEP

John T. Stamp

(*Animal Diseases Research Association, Moredun Institute, Edinburgh*)

Lamb dysentery, blackleg, enterotoxaemia, braxy, and a number of other acute and often fatal diseases of sheep are caused by clostridial organisms of various types. Infection is closely related to the status of the host, and as the rising incidence of some of these diseases is associated with modern methods of grass production and fattening lambs more use must be made of the vaccines and sera that alone can ensure their effective control.

Organisms of the genus *Clostridium* are anaerobic and spore-bearing and live for the most part in the soil and the intestinal tract of higher animals and man. Many of the species of this genus are quite harmless and are active decomposition organisms. Some, however, are responsible for a number of fatal diseases of farm animals and man. Although the symptoms of many of these diseases may be different, the clostridia owe their pathogenicity to their power of forming lethal toxins, some being among the most formidable poisons known.

The natural resistance of animals to these anaerobic bacteria differs very considerably and makes an understanding of their pathogenesis sometimes difficult. There is little dispute about such a virulent infection as lamb dysentery, caused by *Clostridium perfringens* type B, where it would seem that the mere presence of the organism is sufficient to produce the disease; but in other clostridial infections such as pulpy kidney disease of sheep, caused by *Cl. perfringens* type D, consideration must be given to predisposing factors in the host. This relationship between infection and the status of the host is of course a familiar observation among those experienced in sheep husbandry.

There appears to be some evidence that the richer and more fertile a soil the greater are the numbers of clostridia, both of the pathogenic and non-pathogenic types, that are found in it; but as such diseases as lamb dysentery, braxy, pulpy kidney and black disease are of common occurrence in sheep on the hills of Scotland it would seem that an increase in number of the bacteria in the soil is not of overriding importance.

Since the two primary habitats in nature of the clostridial group are the soil and the intestines of apparently normal animals, it is clear that these organisms can never be eliminated from a farm, and consequently that continuing programmes of vaccination are the only feasible methods of reducing losses from clostridial infection. This being so, it is fortunate that veterinary research has provided a number of vaccines and antisera very efficient in the prevention of most of the diseases which are to be described in this paper. These biological products are essentially antitoxic in action and aim to prevent the disease by neutralizing the powerful toxins formed by the pathogens.

As with so many other animal diseases, it is very difficult to assess the economic loss caused by the clostridial group of organisms, but the fact that their occurrence is world-wide suggests that it must be very considerable. Most certainly in Britain the successful control of lamb dysentery, braxy, pulpy kidney disease in sheep and blackleg in cattle has made stock farming very much less hazardous than it was twenty years or so ago. The fact that clostridial diseases also tend to become more serious when intensive methods of farming are employed makes such control even more important in the present phase of world agriculture.

The following paragraphs give a brief description of the various animal diseases caused by members of the *Clostridium* group.

LAMB DYSENTERY

Lamb dysentery is an acute and fatal illness of lambs under three weeks old, caused by *Cl. perfringens* type B. It was a common disease in Great Britain until control methods were discovered, but even now it is not uncommon. It occurs also in Europe and Africa but has not been diagnosed in America, Australia or New Zealand. The causal organism is known to be present in the ground or in buildings and pens on many farms, both hill and arable, especially those in the border counties of England and Scotland, where the disease is said to be endemic. In addition, however, the organism may be carried to clean farms by the purchase of sheep, particularly ewes with lambs at foot, or by carrion-eating birds and vermin, and when this does occur the lamb dysentery bacteria are very apt to remain on the farm and cause the disease year after year.

The fatal illness of the lamb is due to multiplication in the intestine of the specific microbe which, at the same time as it damages the mucous membrane of the bowel, produces a most potent toxin, and this poison when absorbed into the body of the lamb upsets the vital centres and so causes death.

The incidence and type of the disease on affected farms vary greatly. When the disease first appears it causes the loss of only a few very young lambs, but losses become increasingly larger over successive years until the mortality reaches 20–30% of the lambs born. The disease eventually becomes less acute, but at the same time it begins to affect older lambs up to three weeks of age. While the disease is in its peracute phase it kills lambs without producing any observable symptoms, though it generally causes a severe bloody diarrhoea for a day or so before death.

Confirmation of the clinical diagnosis may be made by finding haemorrhagic ulcers in the intestine of a dead lamb, since these are characteristic of lamb dysentery and occur in no other condition. Such ulcers are, however, not always obvious or present, so that in many cases confirmation of the presence of the disease depends on the demonstration of the bacterial toxin in the intestine by biological methods in the laboratory. Although twelve different toxins have been described as being produced by various types of *Cl. perfringens* only two of them are of importance in lamb dysentery: the so-called beta and epsilon toxins, both of which must be present for a positive diagnosis. Considering the serious nature of the disease, its ready confusion with pulpy kidney disease and the expense of the methods of prevention, such confirmation of diagnosis should always be carried out in cases of doubt.

Prevention depends essentially on the use of lamb dysentery antiserum or lamb dysentery vaccine, and no other method of prevention or treatment is of value. Lamb dysentery serum containing the antibodies which react with the toxin is given to all lambs as soon as possible after birth, and in this way each lamb receives immediate protection which lasts long enough for the animal to develop its own age immunity. This method of prevention is more reliable than that based on the use of vaccine; but on many farms, and especially hill sheep farms, inoculation of *all* lambs with antiserum immediately after birth is impracticable, and consequently many farmers use vaccine rather than antiserum. The vaccine consists of an altered and harmless form of the lamb dysentery toxins and is known as a toxoid vaccine. When first used on a farm the vaccine is inoculated twice into each breeding sheep, once in the autumn and again a week or so before lambing, but in succeeding years only the spring vaccination is necessary except in the case of the young ewes which will be carrying their first lamb. Protection of the young lamb is dependent on the presence of antitoxin antibody in the colostrum of the vaccinated ewe, for colostrum when sucked by the lamb during the first twenty-four hours of life is absorbed through the lamb's intestine and so neutralizes the *Cl. perfringens* toxin. This absorbed protective antibody, like the antibody of the injected antiserum, persists in the body sufficiently long to allow the lamb to develop a natural age immunity. On farms where vaccine is used a few deaths from dysentery are to be expected, since an occasional ewe responds poorly to the vaccine or the odd lamb fails to suck enough colostrum during the first hours of life. The convenience of vaccination, however, especially on difficult hill farms, more than outweighs the slight inefficiency of the method.

The lamb dysentery organism can also cause a similar disease in foals and calves, but losses are probably small.

ENTEROTOXAEMIA

This is an acute fatal disease of sheep of all ages, from newborn lambs to aged sheep, but it is probably more frequent in lambs and young sheep, when it is often known as pulpy kidney disease. The infection has a world-wide distribution, and it is the commonest acute killing disease of sheep in Britain at the present time. The condition is called enterotoxaemia because it is directly due to multiplication in the intestines of *Cl. perfringens* type D, which forms epsilon toxin. This toxin is then absorbed into the bloodstream of the sheep, causing sudden death or death after only a few hours of illness. (The type D organism differs from the type B of lamb dysentery only in that the latter forms beta toxin as well as epsilon.) The pathogenesis of the disease is, however, not so simple as this would suggest. It is known, for example, that *Cl. perfringens* type D is frequently part of the bacterial flora of the gut of healthy sheep and that antibodies to epsilon toxin are also often present. It is in fact only under certain conditions that this normally harmless organism can cause death.

There is good evidence that enterotoxaemia is nearly always associated with an increased intake of food or with a change to a richer feed. Numerous instances of this can be given. The classical occurrence of the disease is in lambs in the best or most forward condition as a result of abundant milk in the mother or a plentiful supply of lush grass or concentrate feed. It also occurs commonly in older lambs and hoggs being fed on heavily manured leys or catch crops, on excessive concentrate feeds, or for too long periods on the turnip break. The period of greatest danger is always the few days after sheep are newly introduced to a particular feed, although it is by no means confined to this time. In hill sheep the period of new growth of grass in the early summer is a danger time, especially when the grazings have been improved. Although enterotoxaemia commonly appears with flush feeding, deaths are also relatively frequent in other circumstances, as in sheep in poor or hard condition when they begin to thrive. It is not uncommon for a few losses to occur in ewes in the post-lambing period, or among worm-infested lambs and sheep after they have been given anthelmintic drugs.

The mechanism by which such "eating" factors induce an attack of enterotoxaemia is not well understood, although stasis of the alimentary tract is probably involved. Such restricted movements of the gut would appear to allow epsilon toxin to build up sufficiently to cause death, whereas in the normally functioning gut the rapid flow of intestinal contents prevents the absorption of any appreciable quantity of the bacterial toxin known to be present in healthy sheep. Experimentally, large quantities of *Cl. perfringens* type D organisms or toxin can be administered by mouth to lambs without harm.

On post-mortem examination the changes seen in sheep dead of enterotoxaemia vary considerably. In lambs, but not often in older sheep, the pericardial sac which surrounds the heart is filled with a quantity of straw-coloured or blood-tinged fluid containing fibrin. This and such lesions as blood splashes on the heart muscle and congestion of the bowel are, however, common in other acute diseases, so that the only reliable method of diagnosis is the demonstration by laboratory methods of considerable quantities of epsilon toxin in the intestine of the dead animal. Little reliance can be placed on any pulpy appearance of the kidney, after which the disease in lambs is named, since the importance of this change has been very difficult to assess and it can readily be confused with ordinary post-mortem autolysis of the kidney.

Control depends essentially on preventive methods, for the course of the disease is so rapid that the question of treatment rarely arises. The obvious method of control is dependent on eliminating the predisposing cause or causes, and in practice this means preventing sheep from thriving too rapidly either by putting them on a poorer grazing or by introducing them only slowly to new and better feeds. Unfortunately this defeats the purpose of the stock-owner and if widely applied would negate the advantages of improved grassland production. So far as improved hill grazings are concerned it is of course virtually impossible to control the movement of the sheep, so that in this instance such methods cannot be applied. Nevertheless it occasionally is a useful and inexpensive method of preventing deaths from enterotoxaemia.

Specific preventive methods depend on the use of pulpy kidney antiserum or toxoid vaccine. The latter product is the less expensive but is of no value in controlling an outbreak once it has commenced, for immunity does not develop to a useful level until after the second of the two inoculations, which have to be given at a month's interval. Once immunity has developed as a result of vaccination it persists for a considerable period, probably six months or more. Vaccine is therefore given well before the period of risk, and with lambs this is as soon after birth as possible. After the first two inoculations further vaccination every six months or so continues the immunity through the life of the sheep. Vaccination of ewes, with the lambs becoming immunized by the ingestion of colostrum, is a useful method of protecting lambs during the first two or three weeks of life. Pulpy kidney antiserum, containing considerable antibody to the epsilon toxin, gives immediate protection and is used to control an outbreak already started. This immunity, unlike the immunity following vaccination, only remains useful for a period of ten days or so, so that after this time the disease may reappear. Antiserum is also used to prevent the disease in the first few weeks of a lamb's life, and for this purpose a combined antiserum against pulpy kidney and lamb dysentery is frequently used.

To give sheep complete protection against enterotoxaemia is a considerable undertaking in both labour and expense and on the majority of farms is unnecessary. On the other hand, the intensive methods of present-day agriculture make, for economic reasons, preventive measures against enterotoxaemia an essential practice at some

A sheep dead of braxy. Sudden death without previous symptoms of illness having been observed is a feature of several clostridial diseases.

period of the year. As individual farms vary so much in their management methods it is virtually impossible to give detailed advice, and farmers are recommended to consult their veterinary surgeons for methods of prevention suitable for their own requirements.

Apart from the enterotoxaemia caused by *Cl. perfringens* type D, a further type of this organism causes disease in stock. Type C, which forms beta toxin but no epsilon, is the cause of "struck," an enterotoxaemia of older sheep which was at one time common in the Romney Marsh area of England but which now, for unknown reasons, has almost disappeared. The same organism is responsible for a widespread haemorrhagic enteritis of calves, mainly of the beef breeds, in the United States. The infection is controlled either by vaccination of the mother with *Cl. perfringens* type C toxoid or by antitoxin sera. This calf disease is unknown in Britain.

BRAXY

In Britain up to thirty years or so ago more sheep died from braxy (or bradshot) than from any other disease, losses of 20–40% of yearling sheep being reported from some Scottish farms. It was also an important disease in the Scandinavian countries. Today braxy seems to be of minor importance in the main sheep-raising countries of the world, and even in Scotland it is rarely seen. The reason for this change in incidence is difficult to determine. It could be thought that the widespread vaccination of sheep against the disease which has been practised for many years in such countries as Scotland is the reason, but braxy no longer occurs even on farms where vaccination has been stopped for a number of years, and it has also disappeared in areas where vaccine was never used. On the other hand, the causal organism, *Cl. septicum*, is as ubiquitous as ever and forms part of the normal bacterial flora of healthy cattle, sheep and other animals. It is of course possible that other diseases, such as enterotoxaemia and Pasteurella septicaemia, may have been confused with braxy, thus making its apparent incidence higher than it really was; but this seems hardly likely to have happened often enough to account for such a marked drop in incidence.

Braxy is a very acute disease of young sheep and occurs mainly during the autumn and winter months. Symptoms are rarely seen, the affected lamb or hogg just being found dead, even though it appeared in the best of health a few hours before.

Since the causal organism is widespread it is clear that predisposing factors are of great importance in the production of the disease. As in the case of enterotoxaemia, sheep in thriving condition are the ones usually affected. It is generally thought that the ingestion of frosted food stimulates the disease, but as experimental results suggest that it takes more than severe chilling and the presence of *Cl. septicum* to induce braxy in sheep there is considerable doubt as to the real causal factor. Whatever this may be, it allows the specific organism to become active and multiply in the wall of the true stomach and there secrete its powerful killing toxin.

Diagnosis of braxy depends on the post-mortem findings, which consist of an acutely inflamed, swollen and possibly ulcerated patch on the mucous membrane of the fourth stomach and less frequently in the first part of the intestine. For practical purposes it is unfortunate that these lesions, although obvious in the newly dead animal, quickly become unrecognizable if the carcass is not examined within a few hours of death. In the laboratory large Gram-positive rods can be demonstrated microscopically in the cut surface of the stomach lesion or by impression smear of the surface of the liver. On culture these should be found to be typical *Cl. septicum.*

Inoculation of young sheep with either formalized cultures of *Cl. septicum* or with toxoid provides a high degree of protection against braxy. Vaccination is carried out in the early autumn; double vaccination within fourteen days is practised on some farms. The belief that braxy vaccine causes a check in the thriving of sheep is widely held by flock-masters, but experimental evidence has failed to show that this is so. At the present time it is difficult to assess the need for widespread vaccination, but it is probably "better to be safe than sorry."

BLACK DISEASE

Infectious necrotic hepatitis, commonly called black disease, is again an acute disease, primarily of sheep, which is characterized by sudden death, the causal organism being *Clostridium novyi* (*oedematiens*). The condition is essentially an acute localized infection of the liver.

Black disease occurs throughout the world, having been reported from most regions in which sheep are kept. In Britain the infection was first described in Caithness as the cause of widespread losses, but it has since been seen commonly in other areas of Scotland and in Wales and England.

Although three types of *Cl. novyi*, A, B and C, can be differentiated by their toxins, type B is by far the most commonly involved in sheep disease. Like the enterotoxaemia and braxy microbes, *Cl. novyi* is a common inhabitant of both soil and healthy sheep and cattle, being often present in the resistant spore form; in Britain it does not, however, appear to be so ubiquitous as *Cl. septicum* or *Cl. perfringens*, although its real distribution is unknown. This organism by itself, as with others already described, appears normally to cause no harm to the sheep and becomes dangerous only under certain stimulating conditions, the most common one being the invasion by the liver fluke of sheep in good condition. When the young fluke burrows into the liver it causes damage which stimulates the multiplication of the latent *Cl. novyi*, but the reason for this is not clearly understood. The amount of damage done by the fluke and by the stimulated organism is in itself not very great and would have little or no effect on the health of the animal were it not for the production of a lethal toxin by the bacteria.

As would be expected, black disease occurs only during the period when the liver fluke is active, i.e. during the autumn, winter and early spring months, and it affects both hill and low-ground sheep grazing fluke-infested land. Only adult sheep are affected, the disease being rarely seen in sheep less than two years of age. It occurs more commonly in some years than in others, depending on whether the climatic conditions are suitable or otherwise for the development of the liver fluke.

Symptoms are generally not seen: the affected sheep is found dead lying on its chest with forelegs outstretched and no sign of struggling around it.

Post-mortem examination, if it is to be of any use for diagnosis, must be carried out within a few hours of death, since decomposition after death of the animal rapidly obliterates all lesions. The name black disease is in fact derived from the rapid blackening of the inner surface of the skin due to such post-mortem changes. The specific lesions are seen in the liver, which is generally very congested, with multiple small haemorrhages on its capsule. A characteristic darkening of the capsule over the thin edges of the liver is also present. The cut surface of the liver shows greyish-yellow necrotic areas surrounded by zones of haemorrhage, and it is from these portions of the liver that *Cl. novyi* can be most readily recovered. Other less specific lesions which are characteristic of acute toxaemias are also found. Contrary to what might be expected, only a few immature flukes may be present, so that diligent search has to be made to find them, often using a microscope; more rarely adult flukes are plentiful and easily seen.

If the specific organism is to be cultured it is essential to take specimens *immediately* after death; unless this is done contaminating organisms will make bacteriological examination impossible, for *Cl. novyi* is very fastidious so far as growth in the laboratory is concerned. There are no known methods to show the presence of toxin in the dead sheep.

Since true black disease occurs only in the presence of both specific microbe and liver fluke, prevention can theoretically depend on either the elimination of the fluke or specific vaccination, but as all methods of eliminating the fluke are unsatisfactory the latter is the only practical method. Specific antiserum ensures immediate protection for a period of ten days, but for continuing immunity vaccine is given as well; unfortunately one dose of vaccine is seldom sufficient to give overall control, and it is often necessary to vaccinate two or three times at three-weekly intervals. As vaccination routines vary from farm to farm a veterinary surgeon should always be consulted.

BLACKLEG AND OTHER INFECTIONS

Blackleg, gas gangrene, inflammation of the womb of sheep and several other infections are conditions, all of a similar nature, in which death is caused by infection of the body tissues with one or more of several different clostridia.

Blackleg is a very serious and common disease of cattle and sheep and other ruminant animals in all parts of the world, the causative organism being *Clostridium chauvoei* (*feseri*). The pathogenesis of blackleg is perhaps more difficult to understand than that of some of the diseases already described because a number of observations are conflicting. The causal organism apparently is part of the normal bacterial flora of the intestine of cattle and sheep, but there is little evidence that it is a normal soil saprophyte. Nevertheless a marked difference in the incidence of blackleg in different areas of a country makes it certain that some extrinsic factor must operate. On some farms in Britain even certain fields can be identified as "blackleg fields."

Blackleg, like other clostridial diseases, is an acute fatal condition. On occasion the animal is seen to be acutely ill, and it may be stiff or lame, owing to a rapidly developing swelling under the skin in some well-muscled area of the body. Frequently, however, the animal is found dead without previous illness having been observed. Blackleg is not caused by infection of wounds; breaks in the skin in the region of the local swelling are not seen, so it is generally supposed that the infecting organism is lying dormant in the muscles of the body until conditions become suitable for its growth. Simple ingestion of the organism certainly has no ill effect on the animal. The factors which "trigger off" the infection are also difficult to find, but since almost all outbreaks of blackleg in cattle and sheep occur in animals that are thriving on a high plane of nutrition there seems to be some relationship between nutrition and susceptibility. As incidence tends to be seasonal, climatic factors are likely to be important.

Although it is usually accepted that death from blackleg is due to absorption of a toxin from the local infection, there is little direct evidence of this from the laboratory. Most strains of *Cl. chauvoei* studied have been poor toxin producers, and because the organism does not generalize in the affected animal it can only be assumed that its behaviour in the tissues of the animal is different from that in the test tube.

On post-mortem examination the principal lesion is to be found in one or other of the muscles of the body. The affected tissue is dark reddish-brown to black in colour and of a spongy texture owing to the presence of gas bubbles; the cut surface is dry. The usual signs of generalized toxaemia are also present.

Other diseases very similar in nature to blackleg are commonly seen in all parts of the world in sheep and cattle. In all cases death is caused by infection of tissues with organisms like those already described, *Cl. chauvoei*, *Cl. novyi*, *Cl. perfringens* and *Cl. septicum* all killing quickly owing to their toxins.

In such a condition as parturient metritis it is often assumed that the most frequent accessory factor is bruising or wounding of the tissues of the uterus or vagina; but it is often difficult to determine the actual trauma, and there would appear to be little difference between this condition and true blackleg except for the site of the lesion. On the other hand, the invasion of such wounds as follow castration, docking, clipping or vaccine inoculation might seem to be due to simple contamination, though it is possible that the wound stimulates latent clostridia to multiply and that true wound contamination plays little part.

Symptoms and post-mortem findings in all these conditions closely resemble each other and blackleg except for the location of the primary lesion.

The prevention of blackleg is relatively simple, using hyperimmune serum when cases are occurring or prophylactic vaccination with a vaccine containing toxoid. The organism commonly used for the vaccine is *Cl. chauvoei*, but a product combining *Cl. chauvoei* and *Cl. septicum* is sometimes used on farms where both organisms are thought to cause the disease. When specific preventive measures are to be used against such conditions as metritis in which one or more species of clostridia are involved it is obviously necessary to determine which organisms are responsible so that the appropriate vaccine can be selected.

If the affected animal is seen early in the course of any of these illnesses it is important to use one of the several antibiotics known to be effective against the various clostridial species.

TETANUS

Tetanus, often known as lock-jaw, is an infectious, non-febrile disease of horses, cattle, sheep and other animals caused by the powerful neurotoxin of *Cl. tetani* formed when this organism grows in the animal body. The disease is characterized by the spasmodic contraction of the voluntary muscles, either of single groups or of the entire body.

As with all the other clostridia discussed, *Cl. tetani* lives both in the soil and in the digestive tract of most mammals, including man. Its distribution is world-wide, and the organism is especially common in areas where organic manure is used extensively.

Tetanus generally occurs following the contamination of deep wounds by soil, since the specific organism only grows in a low oxygen potential. It also occurs after such operations as castration and docking, probably because the organism in spore form is already in the damaged tissues and therefore does not need to enter from the outside. On occasion no obvious wound can be seen, especially in cattle, but presumably the organism must be growing in some small lesion that cannot be found, possibly in the intestinal tract.

Tetanus is found more often in the horse than in other farm animals, partly because of the frequency of deep wounds in this species and partly because sheep and cattle develop antitoxin in their sera without ever showing signs of the disease. With the decline of the horse in Britain tetanus has become of less economic importance, and it now occurs only sporadically in other farm animals, although its frequency in sheep has increased since the introduction of the elastic band method of castration and docking, which definitely predisposes animals to infection.

The tetanus organism never invades from the focus of infection but locally produces its toxin, which moves up the nerve fibres centripetally from the peripheral nerves to the central nervous system.

Treatment consists largely in the use as early as possible of hyperimmune antitoxic sera along with penicillin. Serum is also used as a prophylactic when there is a possibility of infection following the occurrence of deep wounds. When necessary, all animals can be easily immunized by giving them two injections of toxoid vaccine, 4–8 weeks apart. Prolonged immunity is maintained by further annual vaccinations. Such vaccination is rarely necessary in the sheep.

Diagnosis is readily made from the clinical symptoms of the affected animal and probably with more accuracy than by laboratory methods.

CONCLUSIONS

In this short discussion of the clostridial diseases of sheep those which occur commonly in Britain have been emphasized, but members of this group cause these and other diseases in different countries of the world. Especially important in the U.S.A. is the disease bacillary haemoglobinuria of cattle caused by *Cl. haemolyticum*. Botulism caused by the toxin of *Cl. botulinum* preformed in the rotting carcasses of animals, the bones of which are later chewed by phosphorus-deficient sheep and cattle, has long been known in Africa under the name "lamsiekte."

As has been seen, clostridial diseases are nearly always fulminating in nature with high fever and rapid progression to death, a syndrome usually associated with virulent highly infectious diseases where the mere presence of the specific microbes is sufficient to cause disease. With the present group of infections this is not usually the case and, since the pathogens are often ubiquitous, the status of he host and predisposing factors must be considered. Unfortunately both the scientist and the stocksman are all but ignorant of the exact nature of these factors, although it is widely recognized that strong, well-grown animals on high planes of nutrition are more liable to be felled by clostridial diseases than those poorly nourished. It seems likely, therefore, that present methods for intensive grass production and selective breeding of animals for rapid growth and early maturity may make it increasingly necessary to apply to sheep and other farm stock the prophylactic measures briefly discussed in this paper.

Livestock Improvement. J. E. Nichols. Fourth edition, revised. Pp. xi+240, with line and half-tone illustrations. Oliver and Boyd, Edinburgh and London. 1957. 16s. net.

For those who are not familiar with this book in its earlier editions it should be pointed out that it was originally written for agricultural and veterinary students and for educated stockowners. In dealing with farm animals and by providing a sound introduction to the genetic and environmental aspects of livestock improvement it served its purpose well. The first edition, published in 1944, was an excellent book and filled a definite gap in agricultural literature. In the two succeeding editions Professor Nichols contented himself with simple revision within the framework of the original, but in this new edition he obviously felt he had to go further, and so he chose a short and easy way of bringing the work up to date by adding a chapter reviewing recent developments and making minor amendments in the text. This comes near to achieving success but, although convenient to the author, detracts from the book as a whole.

After a brief introduction to the subject of livestock improvement and its problems an account is given of the mechanism of inheritance, which is comprehensive but made easily readable by basing the examples on farm stock, many of which can be observed by the practical breeder. The chapters that deal with gene effects and frequency are also useful, but when environmental aspects are discussed, the material, although sound, is somewhat dated. The practical breeder will be interested in the sections on the genetic aspect of selection and on systems of breeding. There is a welcome stressing of progeny testing as the only constructive method of breeding.

The deficiencies of the book become apparent in the chapters on Progeny and Performance Testing and Type and Environment. The review essay towards the end of the book makes good many of the omissions, but most of the material is out of context in relation to the book as a whole.

In cattle breeding the most significant development is the widespread use of artificial insemination, which has placed the breeding policy for very large numbers of cattle in the hands of a few people. This has accelerated the study of the genes in large groups of individuals, or what might be termed population genetics. The advent of A.I. has made it possible to alter the breed structure of the cattle of the country rapidly, and progeny and performance testing is creating a tendency for mathematics to replace the art of breeding. A.I. is not, as yet, a force in the breeding of pigs, sheep and poultry, but again progeny and performance testing is becoming all important.

This is still a good book, well printed and illustrated, and it can be recommended to the student and general reader. The inclusion of a large number of references adds to its value. Perhaps when the next edition is due the author will rewrite much of the book and so bring it back to its original high standard.

D. L. STEWART

Introduction to Agricultural Economic Analysis. C. E. Bishop and W. D. Toussant. Pp. xiv+258, with line illustrations. John Wiley & Sons Inc., New York. Distributed in the U.K. by Chapman and Hall, London. 1958. 42s. net.

The purpose of this latest book from America is to provide a theoretical foundation for the analysis of agricultural economic problems. That it attains its objective is not surprising in view of the firm foundation of economic principles on which the book is based. The great difference in agricultural research in the United States of America and in the United Kingdom is the very real co-operation that exists in America between technical and economic scientists at the planning stage of research programmes. It would be appropriate to suggest that this book should be read by all agricultural research workers in the United Kingdom so that they may be made aware of the economic problems of British farmers which do not differ fundamentally from the problems of farmers throughout the world.

This book is divided into four parts: Introduction, Production and Supply, Consumption and Demand, and Economic Progress.

The first part introduces the economic problems of agriculture and spotlights attention on the three crucial questions: what to produce, how to produce, and how much to produce. These are explored in the second part, although not in this precise order, which is a pity. The economic concepts of opportunity costs, diminishing marginal returns and the principle of substitution are thoroughly set out theoretically, and copious examples from American experimental data are made available. The problem of choice as faced by the practical farmer is threefold. Firstly, he has to choose between products which might be produced, involving decisions about amounts of output and relative prices. Secondly, he has to choose between alternative methods of production, aiming to produce at least cost; this involves decisions about the amount of an input which can be saved by using more of another input, and the relative saving in costs by manipulating the inputs. Thirdly, he has to decide how far he should go in increasing his product by using more of a variable input, for example, increasing applications of fertilizer to boost the crop yield. The varying technical responses which are possible in each of these problems are thoroughly covered, and the effect of changes in prices and costs on the optimum solution is clearly expounded.

One of the more important chapters in the book is that concerned with uncertainty—the real problem of farming. If all the price-cost relationships and all the technical response rates were known the economic problems would cease to exist. The theme of uncertainty could well be developed to the advantage of the farmer-reader. Although there are sections on insurance, diversification, contracting, flexibility and liquidity, the treatment is rather more descriptive than analytical, and examples are conspicuous by their absence.

In the third part, the effect of price and income elasticity of demand on farm incomes is considered. This section might well be read by all farmers who are mystified by marketing phenomena. Economic progress as affected by technical improvement is dealt with in the last part of the book, and the effect on prices and costs is clearly shown.

Although this textbook is designed to equip undergraduates for more advanced courses, it also has a place in the reading of those who wish to understand the principles of efficient farm management.

R. A. MACKNESS

Barley Varieties. G. Aufhammer, P. Bergal and F. R. Horne. Second edition. Pp. xvi+159, with line and numerous half-tone illustrations. Elsevier Publishing Co. 1958. 30s. net.

One of the most successful instances of international co-operation in agricultural research has been the work of the Barley Committee of the European Brewery Convention. The Committee was first appointed in 1947, soon after the foundation of the Convention. Its terms of reference are largely concerned with organizing field trials of malting barleys and reporting on the agronomic performance and malting quality of the varieties investigated. The first trials were laid out in 1950 in Belgium, Denmark, France, Holland, Ireland, Norway and Sweden. By 1957 Austria, Finland, Western Germany, Italy, Portugal and Switzerland had also come into the scheme.

To assist those participating in this work and to provide authoritative information to other malting-barley growers, the Barley Committee arranged for the production of a series of descriptions of the major malting-barley varieties, based on the results of the 1951–2 trials at the National Institute of Agricultural Botany, Cambridge. These descriptions, which included photographs of the ears, were issued as loose-leaf sheets, the authors being F. R. Horne (England) and P. Bergal (France).

The present volume is the second edition of the earlier compilation and is now issued in a more permanent and attractively produced form. G. Aufhammer (Germany), who furnished the German translations in the first edition, now features as a co-author.

Each varietal description is preceded by a full-page plate with photographs of the ear, and dorsal and ventral views of the grains. The description provides information on pedigree, breeder, ear and rachis characters, morphology of the grain and lodicules, agronomic features, habit and pigmentation. Grain quality is assessed in respect of 1000-corn weight, nitrogen content, husk fineness, dormancy, diastatic and proteolytic activities, yield of extract, modification on malting and malting loss. Disease resistance is dealt with rather perfunctorily and for some varieties no information on this aspect is given. Differential varietal behaviour to physiological races of the major pathogens is not considered.

The varietal descriptions are given first in English and then in French and German. The policy adopted in respect of translating varietal names is not entirely consistent. Thus, in the account of the pedigree of Pioneer barley, the French are given the benefit of learning that the designation of one of the parents, Tschermaks zweizeilige Wintergerste, means Tschermak d'hiver à deux rangs; the English reader is left to shift for himself.

A useful feature of the present edition, absent from the first, is the set of charts of varietal pedigrees at the end of the volume. These are arranged according to country and deal respectively with Denmark, Germany, France, Holland, Norway, Sweden and the British Isles.

The movement towards varietal standardization is strong at present, though the dangers of too great a degree of genetic homogeneity are beginning to be realized. The present volume is an excellent introduction to the highly interbred clique of varieties that dominates the present western European scene. R. H. RICHENS

Magnesium: The Fifth Major Plant Nutrient. A. Jacob. Translated from the German by N. Walker. Pp. xii+159, with 8 colour plates and 9 half-tone illustrations. Staples Press Ltd., London. 1958. 40s. net.

The "trinity" of the fertilizer world, NPK, plus calcium are the four nutrients which relegate magnesium to fifth place in the title of this book. There is some logic in this way of looking at things. The need to correct nitrogen, phosphorus and potassium deficiencies has been generally recognized by agriculturists, at least in the more advanced countries, for a long time, and calcium has been applied incidentally in liming materials and many of the common fertilizers. It is only in comparatively recent times that magnesium has been considered more widely; in fact, in many cases it is probable that high levels of production resulting from the use of "complete" fertilizers are responsible for the increasing evidence of magnesium deficiency reported in many parts of the world.

Dr. Jacob has done the agriculturist a service in bringing together much of the information on magnesium which is scattered through the literature (about one-half of the references are published in European journals, mostly German). An excellent introductory chapter briefly covers the chemistry of magnesium. This is followed by a chapter on the magnesium content of plants. The chapter describing deficiency symptoms is understandably uneven, as some crops have been studied much more intensively than others. Deficiency symptoms in almost forty different crops are described, varying from temperate small grains to tropical tree crops, such as cocoa and oil palm. Coloured plates and black-and-white figures illustrate some of these symptoms.

Perhaps one of the most useful contributions is the discussion of ionic antagonism of magnesium with other cations, viz. calcium, hydrogen, ammonium, potassium and manganese. The presence of magnesium as a structural unit of the all-important chlorophyll molecule tends to obscure the fact that it plays a role in various other plant metabolic processes. The author treats each of these in turn and likewise discusses the importance of magnesium in animal and human health.

Magnesium in the soil and methods of measuring it occupy three chapters. The account of fertilizer experiments with magnesium is not of great value, as the soils on which they were carried out are often not indicated. The final chapter is devoted to magnesium fertilizers. The author points out that magnesium has a high "activity factor" and consequently occupies a position intermediate between the other macronutrients and the micronutrients—a deficiency or a moderate excess can be extremely harmful.

On the debit side the book has several irritating features. Incredibly, there is no index! The reference list is a jumble, for the items are strung together in alphabeted blocks. Throughout the book nutrients are not expressed consistently on either an elemental or oxide basis: these are used indiscriminately with, however, a preponderance of the data being expressed as oxides. The English in many places is rather crude—one can almost hear the German accent—and a much freer translation could have been rendered without compromising the subject matter. Nevertheless we must thank Dr. Walker for making the book available to a much wider audience in the English-speaking countries. A. W. MOORE

ABSTRACTS

CROP PRODUCTION

The nation's plant food larder. G. W. Cooke, *J. Sci. Fd Agric.*, 1958, **9**, 761–72.

The history of the use of fertilizers in the U.K. since 1837 is outlined: during this period about 7 million tons of N, 17 million tons of P_2O_5, and 5 million tons of K_2O have been applied. A plant food balance sheet is estimated for 1956. Fertilizers and feeding stuffs supplied about half as much nitrogen as was contained in the crops and grass grown; the balance must have been provided by mineralization of organic nitrogen reserves in the soil, by biological fixation, and by the small amount falling in rain. Much more phosphorus was added than was needed by crops. The potassium applied in fertilizers and feeding stuffs in 1956 supplied little more than a third of the amount taken up by crops and grass; the balance must have been supplied from reserves in the soil. The surface layers of the cultivated soils of the U.K. contain reserves equivalent to about 200 years of N, 100 years of P_2O_5 and 1000 years of K_2O at current rates of fertilizer use. It is concluded that most arable crops grown for sale are now receiving as much fertilizer as can be justified, though a little more nitrogen could advantageously be applied to cereals, and fodder crops should be given fertilizer at about twice the present rate. The optimum rate of application of fertilizer to grass depends on what it is used for, but improvements in grassland management would involve large increases in the total amounts of fertilizers used in the U.K. S.F.A.

Labour aiding in practice. R. Wellesley, *J. Fmrs' Cl., Lond.*, 1958, Part 6, 80–92.

This talk to the Farmers' Club followed the speaker's visit to the U.S.A., where he was impressed and interested in the performance of self-unloading trailers and especially in their application to zero grazing. The uses of self-unloading trailers are listed and include handling of grain, chopped straw and hay, sugar beet, potatoes, fertilizers, and even fencing posts and concrete blocks. On the author's farm these trailers, imported from America, are mainly used to handle grass in zero grazing, which is discussed as an economic method of utilizing grass. E.M.A.

The growth of sugar beet under different water regimes. P. C. Owen, *J. agric. Sci.*, 1958, **51**, 133–6.

In a small plot experiment in which the crop was protected from rain, the application of large amounts of water to keep the soil water stress to a minimum gave very large crop yields. One-fifth of this amount of water gave 80% of the maximum yield. Small, frequent applications of water appeared to give higher yields than the same amount of water in one large application. Yield differences were due to differences in leaf areas rather than to differences in net assimilation rates. (*Author's summary*)

The effect of grazing management on the response of winter wheat to spring defoliation. D. T. A. Aldrich, *Emp. J. exp. Agric.*, 1959, **27**, 10–16.

Small plots of winter wheat at Wye College Farm were clipped on all combinations of the three dates 29th March 1954 (A), 5th April (B), and 12th April (C). All treatments significantly reduced the yield of straw and the number of ears per yard of row. 1000-grain weights were increased by treatments B, C, AB, AC, and BC, but the weights from A and ABC did not differ significantly from those of the unclipped control plots. Grain yields were significantly increased by treatments B, C, and AB, but BC and ABC gave yields similar to the control; the low yields from the control and A are attributed to lodging. In 1956 a field-scale experiment was carried out to compare continuous grazing (2 sheep per 1000 sq. yd. plot during 8th–22nd April), systematic fold-grazing (2 sheep over an equivalent area during the same period), and ungrazed control. There were no significant differences in grain yield, number of ears per yard of row, or 1000-grain weight, and there was no lodging with any of the treatments; the absence of response to grazing is attributed partly to the cold late spring and partly to the use of a late-maturing wheat variety (Banco). S.F.A.

A study of yield and protein response of malting barley varieties to different fertilizers. E. N. Larter and J. Whitehouse, *Canad. J. Pl. Sci.*, 1958, **38**, 430–9.

A study was initiated in 1952 to determine the effect of various fertilizers on yield, protein percentage and saccharifying activity of three varieties of malting barley. The varieties Montcalm, O.A.C.21 and Olli were used throughout a 6-year testing period from 1952 to 1957. During the first four years of experimentation fertilizer treatments included 20 and 40 lb./acre of 11-48-0, 72 and 96 lb./acre of 16-20-0, and 60 lb. of ammonium nitrate. During the last two years of testing, the rates of fertilizer application consisted of 40, 60, 80 and 100 lb./acre of 11-48-0 and 96, 120 and 144 lb./acre of 16-20-0. The combined analysis of variance for yield for each of the two periods (1952–5 and 1956–7) showed fertilizer effects to be significant to the 1% point. A significant "variety × fertilizer" interaction was found to occur for each period and was attributable to the differential response of the three varieties, particularly at high levels of fertilizer application. In 3 of the 5 years in which quality analyses were conducted, crude protein percentage and saccharifying activity of fertilized Montcalm and O.A.C.21 were increased in comparison with control (unfertilized) material. In contrast, the protein percentage of Olli was not influenced by fertilizer treatment in any year. Varietal fluctuations in saccharifying activity values, either between years or between treatments, paralleled those for protein. From the practical viewpoint it is doubtful whether the actual magnitude of protein increases, as found in the present study, was sufficient to consider fertilization as detrimental to malting quality. (*Authors' summary*)

The effect of leys on soil fertility. 2. The effect of undersowing with grass and legumes on the yield of a barley nurse crop. R. H. Jarvis, F. Hanley and W. J. Ridgman, *J. agric. Sci.*, 1958, **51**, 229–33.

Results are given of a trial extending over six seasons from 1952 to 1957 in which barley, drilled at 2¼ bu./acre in 7½ in. rows on a gravelly loam soil, was undersown with six different seeds mixtures, viz. (i) lucerne, (ii) lucerne and cocksfoot, (iii) cocksfoot, (iv) broad red clover, (v) Italian ryegrass and (vi) trefoil. 'Nitro-Chalk' was applied to the seedbed at levels of 0, 1½ and 3 cwt./acre; superphosphate was also applied to all plots, but the potash status of the soil was considered adequate. Yields of hay in the seeding year together with grain and straw yields of barley for the various plots are tabulated. No differences were shown in grain yield, 1000-grain weight or nitrogen content of the grain due to undersowing with any species, indicating that neither competition for nitrogen nor nitrogen excretion by legumes had any effect. It is suggested that undersowing may be carried out without affecting the grain from the nurse crop. E.M.A.

An examination of the method of aggregate analysis by wet sieving in relation to the influence of diverse leys on arable soils. C. R. Clement and T. E. Williams, *J. Soil Sci.*, 1958, **9**, 252–66.

Wet sieving as a measure of the effect of leys on crumb stability is discussed, briefly noting the significant details of sampling and analysis. The increase in water-stable aggregation following several ryegrass/white clover leys of four years' duration was of the same magnitude for both clay and sandy loam soils. The lighter soil, having a lower initial stability, showed the greater proportionate increase. Perennial ryegrass/white clover swards were consistent in giving higher values for water-stable aggregation than other commonly sown grasses. It would seem that a large proportion of clover in a sward would not impair the stabilizing effect of a ley. There was no evidence of any significant variation arising from different methods of grassland utilization. Data from Hurley soil suggest that intensive grazing did not reduce the effect of the grass ley on soil stability as long as a plant cover was maintained. Cocksfoot sown in drills for seed production had less effect on soil than had swards of this grass sown with white clover. The application of 'Nitro-Chalk' to grass leys over a three-year period at annual rates up to 16 cwt./acre had no significant effect on either of the soils examined. Profiles to 1 ft. depth showed that, whereas the high stability found under permanent pasture extended throughout this profile, the increase in water-stable aggregation under a three-year ley was largely confined to the top few centimetres. (*Authors' summary*)

Irrigation of grassland. The influence of irrigation and nitrogen treatments on the yield and utilization of a riverside meadow. I. A. Munro, *J. Brit. Grassl. Soc.*, 1958, **13**, 213–21.

A Thames-side meadow reseeded in 1951 to a timothy/meadow fescue/white clover ley was divided into 48 sub-plots of 1/10th acre. Water treatments were: (1) ½ in. irrigation whenever the soil deficit was 1 in.; (2) 2 in. irrigation when the deficit was 2½ in.; (3) rainfall only. Nitrogen treatment, in addition to a basal dressing of 3 cwt./acre of compound fertilizer (12 : 12 : 15) each March, was 0, ¾, 1½, 2¼ cwt./acre ammonium sulphate after each grazing except the last one in each year. The plots were grazed by 15–18 months heifers in 1955 and steers in 1956. In both years dry matter yields and percentage utilization of the herbage by stock were significantly increased by irrigation; dry matter yields were significantly increased by nitrogen on the irrigated plots but not on the unwatered plots. Irrigation increased the proportions of meadow fescue, timothy and clover at the expense of *Poa* spp. and weed grasses. Nitrogen on the irrigated plots increased the proportion of meadow fescue and reduced the proportions of clover and *Poa* spp. On the non-irrigated plots there was a considerable increase in *Agrostis* and *Holcus* spp. S.F.A.

Influence of phosphate on the botanical composition and on the grade of quality of herbage. F. Sonneveld, A. A. Kruijne and D. M. de Vries, *Netherlands J. agric. Sci.*, 1959, **7**, 40–50.

Since an interim report was published in 1943, the effect of phosphate fertilization on botanic composition (dry weight analysis) was determined in 143 short-term field trials, and the frequency percentages of various species was correlated with phosphate status in over 1000 fields of permanent grassland. The most phosphate-loving species appeared to be *Agropyron repens*, *Alopecusus* spp., *Festuca pratensis*, *Glyceria fluitans*, *Hordeum secalinum*, *Lolium perenne*, and *Poa* spp. The most phosphate-avoiding species were *Agrostis* spp., *Anthoxanthum odoratum*, *Centaurea pratensis*, *Festuca rubra*, and *Rumex acetosa*. The comparatively slight effect of phosphate on *Trifolium repens* was probably because good phosphate status was associated with good nitrogen status. S.F.A

The effect of sheep excreta and nitrogenous fertilizer on the botanical composition and production of a ley. J. L. Wheeler, *J. Brit. Grassl. Soc.*, 1958, **13**, 196–202.

Results are presented for the final two years of a previously described experiment. The return of dung and urine by sheep to a ryegrass/white-clover ley was controlled by suitable harnesses to give four treatments (no dung or urine, dung, urine, dung and urine) which were combined in a replicated factorial design with four levels of nitrogenous fertilizer application (0, 52, 182, 312 lb. N/acre). Applied nitrogen and urine were the dominant factors affecting botanical composition. The percentage of ryegrass increased and that of clover decreased with the progressive increases in nitrogen application. Volunteer species (mainly *Poa* spp.) contributed up to 20% by the final year, the maximum occurring under the medium-high nitrogen treatment. Urine restricted the incursion of weed grasses. Combined with urine or the full return of excreta, high levels of applied nitrogen increased herbage production by up to 120%. There was little response to dung except at the highest nitrogen level. The yield response to applied nitrogen was almost linear. In the absence of animal returns response was poor, partly due to shortage of potash. When both excreta were withheld the light nitrogen dressing depressed the annual production compared with the control; where both excreta were returned together with this dressing no reduction occurred in annual yield and the spring yield was improved ($p<0{\cdot}05$). (*Author's summary*)

The influence on the following arable crop of sheep excreta and fertilizer treatments applied to a ley. J. L. Wheeler, *J. Brit. Grassl. Soc.*, 1958, **13**, 262–9.

In the main experiment the pasture treatments had been: control, dung, urine, and urine + dung, each combined with four levels of 'Nitro-Chalk.' The following crop was winter wheat, which received a basal dressing of P and K but no N. The average response to each increment of 'Nitro-Chalk' was approximately 1 cwt. grain/acre, which was not significant at $p=0{\cdot}05$; there was a significant response to dung, but urine was ineffective. Straw yields showed significant responses to dung, urine, and 'Nitro-Chalk' applications to the ley. In a subsidiary small-plot experiment the above pasture treatments had been combined with P and K, each at two levels. The following crop was marrow-stem kale, which did not receive any further fertilizer treatment. Dry matter showed a significant response to dung, urine, and to 'Nitro-Chalk' except where dung and urine had been withheld; P and K were only effective in the presence of each other. In a discussion of the pasture/arable crop relationship preference is given to the use of high stocking rates with heavy and repeated dressings of nitrogen. S.F.A.

The effect of defoliation on the seed-producing capacity of bred strains of grasses. 1. Timothy and perennial ryegrass. H. M. Roberts, *J. Brit. Grassl. Soc.*, 1958, **13**, 255–61.

Plots of S50 pasture timothy and S101 pasture-hay perennial ryegrass at the Welsh Plant Breeding Station, Aberystwyth, were grazed by sheep in winter, spring, or winter + spring. Both grazed and control plots received 4 cwt./acre of compound fertilizer (12 : 12 : 15) each September and 4 cwt./acre of 'Nitro-Chalk' (15·5% N) each March; the grazed plots received an additional 2 cwt./acre of

'Nitro-Chalk' after each grazing. Winter grazing did not affect the seed yield or uniformity of ripening of timothy and was beneficial to perennial ryegrass. Grazing in spring or winter+spring resulted in uneven ripening of both grasses; the timothy plots had significantly reduced seed yields each year and tended to be rather weedy; with perennial ryegrass the seed yield was not affected by grazing in March and April but was significantly reduced by grazing in May. S.F.A.

Stability of gibberellic acid in contact with fertilizer compounds as shown by response of pinto beans. M. A. Norland and C. J. Erickson, *Agron. J.*, 1959, **51**, 165–8.

The potassium salt of gibberellic acid was mixed at the rate of 1 g. to both 4 and 40 lb. nutrient in various common fertilizer salts and 1 g. to both 20 and 200 lb. fertilizer in 20-20-20 and 10-52-8 compounds. The mixtures were stored at both 10% and 68% relative humidities for periods of 0, 7, 14, 28, 56 and 112 days. The residual biological activity of the mixtures was determined in greenhouse cultures by using a solution of the aged mixture applied to 10-day-old pinto bean plants either as a spray or applied to the soil. Response was shown to the gibberellic acid which had been in contact with fertilizers for periods up to 112 days, but the differences were small in extent. The humidity during storage of the mixtures had little or no effect. Soil applications were slightly less effective than sprays. E.M.A.

The effect of gibberellic acid on Kentucky bluegrass root production. F. V. Juska, *Agron. J.*, 1959, **51**, 184–5.

Kentucky bluegrass was grown in a replicated pot trial involving (1) optimum fertility plus gibberellic acid, (2) optimum fertility without gibberellic acid, (3) low fertility plus gibberellic acid, and (4) low fertility without gibberellic acid. A photograph illustrates the effect of both fertilizer and gibberellic acid treatment on the root and top production after harvest, and a table gives the top and root production. Top growth in g. for the various treatments were (1) 2·43; (2) 1·80; (3) 0·43; (4) 0·30. Root weight was 1·32, 1·91, 0·34 and 0·52 g. respectively. The percentage of roots for the treatments in order was 35·2, 51·4, 44·2, 63·4. The influence of gibberellic acid on root production is compared with that of excess nitrogen. It is stated that additional research is needed to determine whether or not under field conditions root production is reduced by gibberellic acid. E.M.A.

Response of certain varieties of Vitis vinifera to gibberellin. R. J. Weaver and S. B. McCune, *Hilgardia*, 1959, **28**, 297–350.

Two seedless and five seeded grape varieties were treated with the water-soluble potassium salt of gibberellic acid at different stages of the vines' development. Applications were made by dipping clusters or by spraying shoots or entire vines; concentrations ranged from 0·1 to 1000 p.p.m. In all varieties shoot growth was stimulated and internodes were elongated. Treatment of Black Corinth resulted in an excellent set of large berries, and at the higher concentrations berries were elongated. In Thompson Seedless some treatments hastened flowering and produced more elongated clusters and peduncles, others resulted in increased berry size. Flowering was also hastened in Zinfandel and shoots were elongated. Tokay responded with longer leaves and elongated cluster parts. In Ribier and Red Malaga no beneficial results were obtained by dipping clusters, but spraying often hastened coloration slightly and sometimes produced higher Balling readings. Dipping flower clusters of Muscat of Alexandria failed to increase the percentage of set. Considerable numbers of shot berries resulted from some treatments of Thompson Seedless, Zinfandel, Tokay, and Ribier. (*Authors' summary*)

CROP PROTECTION

The mechanism of the control of turnip flea beetle by benzine hexachloride dressings on brassicae seed. H. R. Jameson, *J. Sci. Fd Agric.*, 1958, **9**, 590–6.

Laboratory experiments have shown that kale seedlings recently emerged from seed treated with BHC are highly toxic to flea beetle. This toxicity falls rapidly in the week following emergence of the seedlings, but their protection against material damage by flea beetle is maintained for another 2 or even 3 weeks. The experiments indicate that initial protection is due to BHC from the seed dressing contaminating the seedling leaves directly. When the plants are about a week old the insecticide reaches the leaves systemically through the roots; some is then volatilized through the leaves in amounts causing low mortality of the insect but nevertheless preventing it from causing serious damage to the plant. (*Author's summary*)

Biological activity of several 0,0-dialkyl alpha-acyloxyethyl phosphonates. B. W. Arthur and J. E. Casida, *J. agric. Fd Chem.*, 1958, **6**, 360–5.

As Dipterex is distinguished by its low mammalian toxicity, a series of *o,o*-dialkyl 2,2,2-trichloro-1-acyloxyethylphosphonates and related derivatives were compared for their toxicity to *Musca domestica* and to rats and for their anticholinesterase activity. The most selectively toxic was butonate (*o,o*-dimethyl 2,2,2-trichloro-1-*n*-butyryloxyethylphosphonate); it was equal to Dipterex in its control of *M. domestica*, and much less toxic to rats. Its metabolism, examined in insects and rats and *in vitro* with mammalian tissue, was variable, and hydrolysis at different sites was held to account for its selectivity. D.L.

Chemical control of insects attacking alfalfa in southwestern Ontario. K. G. Davey and G. F. Manson, *Canad. J. plant Sci.*, 1958, **38**, 34–8.

Several species of Hemiptera, notably *Philaenus leucophthalmus*, *Acyrthosiphon pisi*, *Empoasca fabae* and *Liocoris lineolaris*, were found in 1953 and 1954 to infest lucerne in south-western Ontario. Only small numbers were present in fields in the spring, but populations built up as the season advanced and, although they were temporarily checked by the cutting of hay, they approached pest status later in the year. The use of wettable malathion, Perthane, toxaphene or heptachlor in mid-May at rates of 0·5, 1·0, 1·25 and 0·38 lb./50 gal. water/acre respectively prevented nymphs of *P. leucophthalmus* from assuming pest proportions and kept the numbers of *Lygus* spp. at low levels for about two weeks; malathion had an economic effect on *A. pisi* for 10 days. There were increased yields from the first cuttings of hay except after treatment with heptachlor, which was phytotoxic. Treatments applied after the first and second cuttings, on 9th July and 11th August, did not result in increased yields, except that malathion and ethyl-DDD reduced the amount of injury caused by *E. fabae*. D.L.

Recent trials with newer acaricides in British Columbia orchards. R. S. Downing, *Canad. J. plant Sci.*, 1958, **38**, 61–6.

A range of the more modern acaricides was tested in field trials in recent years to assess their effectiveness against red-spider mites in British Columbia. Good control of *Bryobia arborea* and *Metatetranychus ulmi* was obtained with 50% wettable chlorfenson (*p*-chlorophenyl *p*-chlorobenzenesulphonate) at a rate of 2 lb./acre, 20% wettable chlorbenside (*p*-chlorobenzyl *p*-chlorophenyl sulphide), or 1 gal.

of 50% emulsifiable Genite 923 (2,4-dichlorophenyl benzenesulphonate), or 8 lb. of 18·5% Kelthane (1,1-*bis*(*p*-chlorophenyl)-2,2,2-trichloro-ethanol), all at 75 gal./acre applied at the pink-bud stage. Sprays applied at the same rate of 25% wettable chlorbenzilate (ethyl 4,4′-dichlorobenzilate) at 8 lb./acre, or 4 lb. of Trithion (*o,o*-diethyl S-*p*-chlorophenylthiomethyl phosphorodithioate) gave good control of *M. ulmi*, but were not used against *B. arborea* at the pink-bud stage. Trithion gave good residual control of both mites when applied in summer, and the summer use of Kelthane was effective against *Bryobia*. Wettable diazinon gave good initial control, but was not persistent enough for good general control. Both chlorfenson and chlorbenside injured apple foliage when they were sprayed at pink-bud, and summer sprays of these acaricides or of fenson damaged the fruits of some varieties. D.L.

Artificial mutagenesis in plant breeding. D. R. Davies and E. T. Wall, *Nature, Lond.*, 1958, **182**, 955–6.

Attempts failed at the Radiation Laboratory, Wantage, Berks., to produce mutants of Proctor barley that were resistant to *Erysiphe graminis* f. sp. *hordei*. Seedlings raised from γ-irradiated seed were inoculated at the two-leaf stage with conidia; none showed any degree of resistance. It was concluded that, as the results differed so markedly from work elsewhere with the induced resistant form of barley known as Volkorn, probably many hundreds of loci are involved in the determination of mildew resistance. D.L.

Control of covered kernel smut (*Sphacelotheca sorghi*) of grain and black loose smut (*Ustilago avenae*) of oats with gibberellic acid in greenhouse studies. L. L. Farrar, 1958, *Plant Dis. Reptr*, **42**, 1254–61.

In initial glasshouse experiments at Georgia Experiment Station, grain sorghum plants at the 3-leaf stage, seed-inoculated with teliospores of *S. sorghi*, were sprayed with gibberellic acid in 95% ethanol at concentrations of 10, 100 and 1000 p.p.m. At maturity, the highest concentration of gibberellic acid was shown to have given excellent control with 1 diseased head out of a total of 50, compared with 25 out of 57 on untreated plants. The lower concentrations were not effective. In a similar trial with *U. avenae* on oats there was 7·3% smut on plants treated with 1000 p.p.m. gibberellic acid and 21·6% on controls. As a seed treatment, gibberellic acid gave total control of smut at 2000 and 1000 p.p.m. Germination was accelerated; plants were about twice the height of controls at 14 days, but there were no appreciable differences at maturity. The probable modes of action of gibberellic acid in disease control are discussed and the literature is reviewed. D.L.

"Blast" produced by the artificial defoliation of oats. D. W. Empson, *Plant Path.*, 1958, **7**, 85–7.

That a reduction in leaf area could induce the condition of oats known as "blast" was shown in a plot experiment conducted by the N.A.A.S. at Wolverhampton. Each leaf on plants of Sun II was removed about ¼ in. above the ligule in different plots on 8th (29 days after sowing), 15th, 22nd May, 4th 19th, 26th June and 3rd July. All the panicles had emerged by 9th July, and it was then obvious that symptoms of severe blast were present on plants that had been defoliated on 19th and 26th June. Blast is thus probably an indication of reduced vitality at a critical period in the development of the plant, such as could be caused by adverse weather or by insect attack; it is not caused by factors continuously present, such as mineral deficiency. D.L.

Blister blight control in 1957 with respect to fungicide formulation, application rates and yield. T. Visser, N. Shanmuganathan and J. V. Sabanayagam, *Tea Quart.*, 1958, **29**, 9–20.

The general effectiveness of copper fungicides against tea blister blight was emphasized in field trials carried out during the 1957 south-western monsoon on the St. Coombs Estate, Ceylon. Yield differences were not significant between the use of 50% Perenox, 50% Copper Sandoz, 70% red copper, 35% Cupravit Blue or 50% Shell Copper, nor between application rates of 6 or 8 oz./acre. At 3 or 4 oz./acre all the materials gave reasonable protection to fields being picked under moderately severe monsoon conditions. An average loss of 16% yield was recorded in untreated plots. D.L.

Spray application problems: XLII. Mercury deposits on apple fruits and foliage. J. T. Martin and J. A. Pickard, *Rep. agric. hort. Res. Sta., Bristol*, 1958, **1957**, 76–81.

Weathering was found to disperse mercurial surface deposits between applications in the course of a 7-application spray programme with 0·003% phenyl mercuric acetate on Bramley's Seedling apple trees at Long Ashton. There was some penetration of fruits and leaves, and determinations from stored fruit showed the presence of 0·05 p.p.m. mercury, equivalent to 10 µg./fruit, which was mostly located in the pulp (8 µg.); the peel contained 2 µg. and the core less than 1 µg. Detectable amounts were also present after baking. D.L.

Herbicides in Kenya coffee. J. A. N. Wallis, *Pest. Abstr. News Summ. C*, 1958, **4**, 146–72.

In trials conducted between 1954 and 1957 consistently good weed control in coffee was obtained with 2·5 lb. PCP plus 2,4-D amine or isopropyl ester at 1 lb. a.i./acre, and with 2,4-D at 1 lb. a.i. plus dalapon at 3·7 lb. a.i./acre, both applied early in the April–May and November rain seasons. An aromatic oil emulsion fortified with PCP caused a bricky off-flavour most obvious after application by hooded lance. A slight unclassified flavour was noticed with the 2,4-D plus dalapon mixture, but the differences between treated and untreated plots were not significant. Dalapon at 7·4 lb. a.i. in 80 gal./acre applied during the dry season controlled the top growth of couch (*Digitaria scalarum*), but regrowth occurred after two months. The same rate applied during and at the end of the wet season gave complete couch control for three months. Preliminary rotary cultivation of the infested area did not increase the effect of dalapon. Neither single nor combined applications of ATA at 2–4 lb. a.i./acre or PCP at 2–4 lb. a.i./acre controlled couch, nor did either chemical enhance the effect of dalapon. ATA and PCP both gave temporary control of broad-leaved weeds, the best results being with ATA at 4 lb. a.i./acre. The coffee damage caused by ATA and dalapon is described; the dalapon injury was associated with rates over 7·4 lb. a.i./acre applied to the tree base when the trees were growing actively. Rhizomes from plants treated with dalapon at 10 lb. a.i./acre produced as healthy growth as those from untreated plants. Dalapon at rates over 2 lb. a.i./acre pre-weed emergence reduced couch growth; 16 lb. a.i./acre completely inhibited development. Under natural conditions dalapon at 8 lb. a.i. in 80 gal./acre was translocated not more than 3–6 in. along the rhizomes. Small-scale observation plots on mature coffee bushes are described; the chemicals tested alone and combined were dalapon, ATA, MCPB, simazin, monuron, MH, aromatic oil and CIPC. R.L.W.

Some studies on the herbicidal properties of maleic hydrazide. A. S. Crafts, H. B. Currier, and H. R. Drever, *Hilgardia*, 1958, **27**, 723–57.

Tests were conducted to improve the formulation of maleic hydrazide (MH) with respect to absorption and to add to its lethal action. It was found that surfactants and humectants intensify the effects of MH, that water-soluble forms are more effective than oil carriers, and that high humidity promoted absorption. Effectiveness, as judged by extent of regrowth, was also increased somewhat by aftertreatments with toxic aromatic oils, repeated sprays of MH, follow-up applications of sodium chlorate, and simulated tillage treatments performed several days after spraying. Disturbance of plants two months after treatment, however, seemed to break dormancy. MH-induced dormancy was more prolonged in old, well-established Bermuda grass cultures than in new ones; however, MH sprays on annual grass cultures at different stages of maturity proved that young plants showed more injury than old ones.

(*Authors' summary*)

Increasing the hatching of eggs of cyst and rootknot nematodes with nabam. P. M. Miller and E. M. Stoddard, *Science*, 1958, **128**, 1429–30.

Nabam (disodium ethylene bisdithiocarbamate) in tap water at 0·55 g./l. reduced the hatching of *Meloidogyne* eggs, yet in the presence of soil it increased the hatching rate and also dissolved the adhesive material of egg-masses. A decomposition product of nabam in the soil was therefore presumed to be a hatching factor, and its value in association with a known nematicide (V-C13; *o*-2,4-dichlorophenyl-*o*,*o*-diethyl phosphorothioate) was examined. V-C13 was applied as a soil drench at 0·25 ml./l. alone and with nabam at 0·55 g./l. to tomatoes in *Meloidogyne*-infested glasshouse soil. The average percentages of galled roots were 33, 60, 10 and 50 from V-C13, nabam, V-C13+nabam, and control groups respectively. A hatching stimulus was also shown by nabam on *Heterodera tabacum*. Other fungicides, known to be decomposition products of nabam, had no effect, neither had growth-promoting substances such as α-naphthaleneacetic acid or 3-indoleacetic acid. D.L.

The effects of arboricides on East African trees and shrubs—I. Acacia spp. G. W. Ivens. *Trop. Agri., Trin.*, 1958, **35**, 257–71.

Trials conducted in Tanganyika and Kenya in 1954 to 1956 showed that aerial parts of most *Acacia* spp. can be killed by 2,4,5-T esters in oil; 2,4-D esters in oil were slightly less effective. 1% 2,4,5-T esters in oil applied as a basal spray to unfrilled bark gave effective control and reduced regrowth of two small tree species, *A. hebecladoides* and *A. zanzibarica*. 0·5%, 0·6% and 1% basal sprays applied to frilled bark gave complete kill and excellent regrowth control of the large tree species *A. nigrescens*, *A. tortilis* and *A. senegal* respectively. *A. pennata*, a climbing shrub, regenerated very rapidly after treatment; repeat sprays of 0·5% 2,4,5-T would probably be necessary for complete control. The basal sprays were effective on the non-regenerating species all the year round; the regenerating species were treated most successfully during the period of active growth. Treatment of standing trees was more effective than cut stump treatment. Other chemicals tested, including 2,4,5-T esters in water, MCPA and ammonium sulphamate, were not effective. R.L.W.

ANIMAL HUSBANDRY

The potential nutritive value of some weeds common to north-eastern England. C. B. Fairbairn and Brynmor Thomas, *J. Brit. Grassl. Soc.*, 1959, **14**, 36–46.

Protein, ether extractives, crude fibre, nitrogen-free extractives, ash, silica, calcium, phosphorus, magnesium, potassium, sodium, chlorine, iron, manganese, copper, and cobalt contents of 20 species of weeds are tabulated. The majority are either toxic or occupy situations usually inaccessible to grazing animals, but the common dandelion, the common stinging nettle and the creeping thistle are considered potentially valuable food for stock, and the spear thistle, stitchwort, cleavers, crosswort and bird's-foot trefoil are considered of moderate nutritive value. S.F.A.

Partial wilting of grass crops for silage. 1. Field trials. M. J. Nash, *J. Brit. Grassl. Soc.*, 1959, **14**, 65–73.

In moderate to very good weather the average moisture content of long herbage at Edinburgh was reduced from 85% to 74% by wilting for 9 hours and from 83% to 70% by wilting for 24 hours. In poor to very poor weather the figures were 86% to 80% in 9 hours and 85% to 81% in 24 hours (but overnight rain raised the moisture content to 86·5% at the 18th hour). A comparison of bruised with mown herbage showed very little difference in overall rate of wilting but the tops of the bruised swaths dried out very quickly; the bruising caused the herbage to settle on the ground, so reducing the circulation of air through the bottom of the swath. Another trial showed that it was better to cut as early as possible in the morning than to wait for the uncut crop to dry. Except in the trials with bruised material no dry-matter losses occurred. S.F.A.

A study of factors affecting feed intake and the eating behaviour of cattle. J. E. Duckworth and D. W. Shirlaw, *Anim. Behav.*, 1958, **6**, 147–54.

Four in-calf Ayrshire heifers were fed chopped or unchopped silage; the treatments were reversed after seven days. Chopping significantly reduced the average daily intake of wet silage, the amount of dry matter consumed, the time spent eating, and the number of boli produced in cudding, but increased the number of bites of eating, the speed of eating, and the number of chews cudding. In a second experiment the same heifers were fed grass cut fresh or dried for 30 minutes. Appetite was limited by the wet matter intake when the percentage dry matter was below about 24% and by the dry matter intake when the percentage dry matter was above about 28%. On the dry diet more liquid water was consumed, giving a fairly constant total water intake. Drying increased the speed of eating and reduced the number of bites of eating, but had no significant effect on the cudding behaviour. S.F.A.

Studies in grazing management. 7. The influence of strip grazing versus controlled free grazing on milk yield, milk composition, and pasture utilization. G. W. Arnold and W. Holmes, *J. agric. Sci.*, 1958, **51**, 248–56.

Treatments compared on a short rotation ryegrass/timothy/white clover 3-year ley were strip and free grazing of the pasture receiving either five dressings of 3 cwt. 12 : 12 : 15 or 0 : 16 : 16 compounds in 1956 and 80% of these amounts in 1957. Strip grazing was carried out by means of electric fencing. Tables show the effect of grazing on liveweight increases in dairy cows during both seasons, the effect of grazing and fertilizer treatment on milk composition and feed intake during 1956, and the total production per acre during both seasons. In both years no difference in milk yield per cow due to treatments is shown, nor in 1956 was milk yield or milk composition affected by grazing treatment, fertilizer treatment or the provision of straw. Total yield per acre was not affected in either year by grazing methods. The response to nitrogenous fertilizer was small, averaging 3 lb. S.E./lb. nitrogen applied. E.M.A.

A comparison between an early weaning and a more conventional system of rearing dairy calves. M. E. Castle and J. N. Watson, *Anim. Prod.*, 1959, **1**, (1), 31–6.

Two groups of 12 Ayrshire heifer calves were reared from birth to 14 weeks on two contrasting systems. The conventionally reared group consumed 19 gal. of milk, 86 gal. of milk substitute and 195 lb. of calf meal (17·0% crude protein in dry matter) in 14 weeks, whereas the early-weaned animals consumed 5 gal. of milk, 19 gal. of milk substitute and 259 lb. of early-weaning cubes (22·7% crude protein in dry matter) in the same period and were weaned from milk substitute at 5 weeks old. All the calves had unlimited access to dried grass (12·0% crude protein in dry matter). The mean live-weight gain of the calves on the conventional system was 1·26 lb./day and of the early-weaned animals 1·20 lb./day. These values were not significantly different. None of the experimental calves had bloat or indigestion, and there was only one minor outbreak of scour. At the present-day prices of the foods, the early-weaning system was the cheaper system both per day and per pound of live-weight gain.
(*Authors' summary*)

Cobalt bullets. E. D. Andrews, *N.Z. J. Agric.*, 1958, **97**, 427–9.

New Zealand experiments are described in which administration of a hard, dense bullet containing 75% or 90% cobaltic oxide to both weaned and unweaned lambs, hoggets and ewes was compared with dosing with cobalt to control bush sickness. Feeding a 75% cobalt bullet to weaned lambs gave average liveweight increases of 24 lb. compared with 23 lb. for the group receiving weekly cobalt dosing, while the untreated control lost 7 lb. over the four-week trial period. After recovery from the forestomachs the bullets were coated with insoluble calcium phosphate, but it is thought unlikely that in this test the deposit rendered the cobalt unavailable. Hoggets were used to compare feeding a 90% cobalt bullet with copper dosing. Highly significant gains were made by the bullet-treated animals, while the copper dosing gave no better results than in the untreated controls. In trials with unweaned lambs the bullets were fed to animals at 6–9 weeks of age, this treatment again being compared with weekly dosing of cobalt. From 16th October to 25th March the bullet-treated group made average liveweight gains of 32 lb. and the cobalt-dosed group gained 31 lb., while the untreated controls all died of cobalt deficiency. Evidence suggests that in the case of unweaned lambs the bullets may become so heavily coated with deposits that they may be rendered ineffective after a few weeks. Feeding of cobalt bullets also appears as a practical method for controlling cobalt deficiency in ewes. E.M.A.

Sideways creep grazing for intensive lamb production. C. R. W. Spedding and R. V. Large, *J. Brit. Grassl. Soc.*, 1959, **14**, 17–28.

Five paddocks each of ⅗ acre were divided in half by a fence, one side being a creep; 21 ewes and their 35 lambs were moved at intervals of not more than 4 days in such a way that the ewes never entered the half reserved for the lambs; when necessary the area grazed only by lambs was gang-mown. This system was compared with rotational grazing by a similar group of ewes and lambs of three 1-acre paddocks. Liveweight gains per acre in 1957 and 1958 respectively were 955 and 983 lb. with sideways creep and 870 and 926 lb. with rotational grazing. Sideways creep produced 74% and 77% grade A carcasses and the rotational management 43% and 53%. Worm infestation was considerably less with the sideways creep. S.F.A.

Feeding and management of pregnant sows on pasture. D. E. Eyles, *Anim. Prod.*, 1959, **1**, (1), 41–50.

Wessex Saddleback sows were fed 4 lb. or 2 lb. of a balanced meal per head per day during the first 13 weeks after mating; all sows received 6 lb. of meal for the last 3 weeks of pregnancy and 4 lb. + 1 lb. for each piglet during lactation. From mating to weaning half the sows on each feeding treatment had access to small soil pens and the other half to range grazing of lucerne or grass/clover swards. Piglet mortality was highest with sows which had been fed 4 lb. of meal and were confined in soil pens, because this treatment produced over-fat sows. There was no difference in number of piglets per litter at birth or mean piglet weight at 3 weeks and 8 weeks. In a supplementary trial 3½ lb. of dried grass and ½ lb. of meal per head per day were fed to gilts during the second and third months of pregnancy without adversely affecting farrowing results. S.F.A.

Magnesium metabolism in the dairy cow. 1. Metabolism on stall rations. J. A. F. Rook, C. C. Balch and C. Line, *J. agric. Sci.*, 1958, **51**, 189–97.

This work forms part of an extensive investigation into the magnesium metabolism of cattle designed to explain the development of all forms of hypomagnesaemia. Dairy shorthorn cows in milk were fed on five experimental rations in the stall, viz. (i) hay + dairy cubes, (ii) hay + dairy cubes + decorticated groundnut meal, (iii) hay + concentrates, (iv) hay + grass silage + concentrates, (v) hay + mangolds + concentrates. Tables show the contribution of the different foods in the rations to the total intake of magnesium, and the intake, excretion in the faeces and urine, secretion in the milk and body retention of magnesium in cattle fed the various experimental rations in the stall. Wide differences in the utilization of the magnesium in these typical winter rations were observed. Body retention of magnesium ranged from −1·5 to +5·6 g./day. Significant relationships between the blood serum magnesium level and both the excretion of magnesium in the urine and the urinary concentration of magnesium were observed. The results suggest that the renal threshold for magnesium is of the order of 2·0 mg./100 ml. blood serum. E.M.A.

Magnesium metabolism in the dairy cow. 2. Metabolism during the spring grazing season. J. A. F. Rook and C. C. Balch, *J. agric. Sci.*, 1958, **51**, 199–207.

The ration of experimental dairy cows was abruptly changed from typical winter rations to freshly cut herbage fed twice daily before milking and offered in excess of appetite. Details are given of the botanical composition and previous fertilizer treatments of the swards used to provide herbage, of the quantities of herbage and any supplementary feed offered to the cows, and of the intake, excretion in the faeces and urine, secretion in the milk and body retention of magnesium in the cows fed herbage cut at both early and mature stages of growth. The composition of the different swards offered and the intake and utilization of magnesium by the cows is tabulated. Intake of herbage magnesium by individual animals varied from 9·5 to 15·2 g./day, while the supply of "available" magnesium varied from 0·5 to 4·2 g./day. When winter rations were changed to cut young grass an immediate fall in urinary magnesium excretion took place, coupled with development of hypomagnesaemia in animals where the urinary magnesium excretion fell to zero. This was less marked when more mature grass was fed.

E.M.A.

The effect of chlortetracycline on growth of early-weaned calves. T. R. Preston, N. A. McLeod and P. K. Dinda, *Anim. Prod.*, 1959, **1**, (1), 13–19.

Twenty-eight calves were fed reconstituted buttermilk from the 3rd to the 20th day, hay and water *ad lib.* from the 7th day, and a concentrate mixture from the 14th day. Addition of chlortetracycline to the concentrate mixture increased significantly the rate of liveweight gain between the 28th and 56th days and between the 56th and 84th days, the skeletal growth between the 3rd and 84th days, the consumption of concentrates between the 14th and 56th days and between the 14th and 84th days, and the concentrate conversion rate. Addition of chlortetracycline to the buttermilk had no significant effect on any of the above measurements, nor did it make any significant difference to the effect of adding chlortetracycline to the concentrate mixture. It is suggested that one of the effects of feeding antibiotics is to reduce gas production by rumen bacteria, with the result that the animal eats more food.

S.F.A.

Efficacy of oat hay as a legume bloat preventative in cattle. H. W. Colvin, Jr., P. T. Cupps and H. H. Cole, *J. Dairy Sci.*, 1958, **41**, 1557–64.

This trial was carried out by the University of California on 17 dry Jersey and Holstein cows which were kept on a dry lot with access to water but not to feed when not grazing relatively pure stands of a succulent, immature lucerne pasture of height 12–16 in. Grazings were made six times daily (four in the morning, two in the afternoon), and during the test period of four days excellent quality oat hay was fed overnight to appetite, but this supplement was withheld during the pre- and post-test periods, also of four days' duration. The overnight feeding of an average of 12 lb./head oat hay significantly reduced the incidence and severity of acute legume bloat. It is suggested that the hays act by preventing the formation of froth, or they contain an anti-frothing chemical, or their scabrous nature causes stimulation of rumen receptors responsible for maintaining the tonic activity of rumen motility and eructation by reflex action.

E.M.A.

Clinical studies on bovine ketosis. 1. Reduced milk yield associated with subclinical ketosis. R. H. C. Penny, *Vet. Rec.*, 1958, **70**, 641–4.

An outbreak of subclinical ketosis in which ACTH (adrenocorticotrophic hormone) was used as a treatment in an Ayrshire herd of recently calved cows is described. Diagnosis of the disorder was made by a modified Rothera's test. Graphs show milk yield and ketone excretion for the individual animals as affected by stage of lactation, levels of silage feeding and turning out to grass. Daily fluctuations in milk yield of up to 10 lb./cow were observed. Following a reduction of more than 50% in the silage fed there was a rapid fall in the number of cows excreting ketones. A further less spectacular fall took place when the cows were turned out to grass. A future paper is to evaluate the use of ACTH in this herd.

E.M.A.

Observations on experimental parasitic bronchitis in calves and the response to diethylcarbamazine. W. H. Parker and H. E. Roberts, *J. comp. Path.*, 1958, **68**, 402.

Earlier work by Parker indicated the need to discover the optimum method of treatment of early lungworm infestation with diethylcarbamazine. Seventeen Ayrshire bull calves purchased from one farm at a few days old were each given 10,000 infective *Dictyocaulus viviparus* larvae by stomach tube at 3½–4 months old. They were divided into four equal groups except that the control group contained one extra calf, which was very small, suffered more severely than the others and was excluded from the general results and averages. Clinical observations, weekly weighings and faecal examinations were made throughout. Respiratory rate increased from about the 7th day after infection and rose to around twice normal by the 14th day. Three groups of four calves were treated with diethylcarbamazine citrate freshly dissolved 10% WV in sterile distilled water as follows: (i) 10 mg./lb. bodyweight orally; (ii) 10 mg./lb. intramuscularly; (iii) 1 mg./lb. intramuscularly. To test development of immunity two calves from the groups which received the 10 mg. doses and the control group were challenged on the 44th day with 15,000 infective larvae. The experiment was terminated on the 82nd day, when all were slaughtered and examined post-mortem. A fall in bodyweight of approximately 5% occurred in all groups during the second week. Subsequently each group gained steadily but at different rates up to the 35th day. Groups which received 10 mg./lb. of the drug gained over 2 lb. during the 3rd, 4th and 5th weeks compared with 1·1 lb. and 0·4 lb. in the control and 1 mg.-dosed groups respectively. It was concluded that the drug in daily doses of 10 mg./lb. for 5 days commencing 14 days after infection terminated a moderate infestation, but doses of 1 mg./lb. intramuscularly were ineffective. Intramuscular administration was only slightly superior to the oral route. Clinical response commenced at once and resulted in superior weight gain. Reaction to challenge suggested that immunity in treated calves was lower than with patent infection. Persisting parasitic lesions were present in both treated calves and controls at post-mortem examination.

F.W.W.

Selenium poisoning in horses in north Queensland. S. G. Knott, C. W. R. McCray and W. T. K. Hall, *Qd J. agric. Sci.*, 1958, **15**, 44–58.

A condition in horses involving laminitis and loss of mane and tail hair, known as "changed hoof disease," has occurred in Cape York Peninsula, Queensland, from the time the area was first settled in 1864. The condition was investigated in 1955 and found to represent a syndrome of selenium poisoning. Selenium contents of 2·6, 12·0, 6·0 and 6·8 p.p.m. respectively were found in the liver, mane, tail and hoof of one horse, and of another the mane and tail contained 2·5 and 1·0 p.p.m. of selenium. The source of selenium, confirmed by feeding trials, was the rubiaceous plant *Morinda reticulata*. The leaves of this plant commonly contained more than 300 p.p.m. of selenium; such a level is higher than that for pasture plants in Irish toxic areas, and much higher than levels reported from the U.S.A., and probably indicates that *M. reticulata* is a selenium accumulator.

D.L.

Printed in Great Britain at THE KYNOCH PRESS, *Birmingham*